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THE
ECONOMY OF NATURE
EXPLAINED AND ILLUSTRATED
ON THE
PRINCIPLES
OF
MODERN PHILOSOPHY.

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IN THREE VOLUMES.
WITH FORTY-SIX PLATES.

VOL. III.

LONDON:
PRINTED FOR J. JOHNSON, N^o 72, ST. PAUL'S CHURCH YARD.

1796.

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OF VEGETABLES.

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A DISTINCTION has been established by philosophers, which is not destitute of utility, though it must be confessed that in this, as in every other instance which regards the system of nature, the line of demarcation is scarcely defined with sufficient precision.—All natural bodies have been classed under two grand divisions; unorganized and organized bodies. If the phrase *vegetable life* might be freely admitted, it would be consistent with correctness to term the former the inanimate, and the latter the animated parts of creation. Through the former of these regions we have already travelled with some diligence, though it is to be apprehended

hended not without pain and difficulty to the reader: for an author is but seldom an adequate judge of the degree of entertainment which his labours are capable of affording to others.—The latter, which includes what the old writers denominate the vegetable and animal kingdoms, remains to be considered.

Unorganized bodies, we have seen, consist of simple combinations of a vast variety of different elementary principles. Organized bodies, on the contrary, consist of few principles; but in the proportions, combinations, and arrangement of these principles, they are infinitely varied; and their structure is as complex, as their materials are simple. Thus, in the mineral creation we may enumerate not fewer than thirty-three distinct elementary principles; the vegetable creation for the most part consists only of three; and the utmost to which it can be extended, is about six or seven distinct species of matter, which occasionally enter into the composition of those varied beauties, that singularity of structure, that vast assemblage of organized bodies, so different in qualities and external appearance, which the woods, the fields, and the gardens, present to our view: so numerous that they have hitherto eluded the art of the most skilful botanist to methodize and arrange.

The constituent or elementary principles of vegetables, are hydrogen, oxygen, and charcoal. These, as far as our observations have hitherto extended, are common to all vegetables. There are some other substances, such as calcarious earth, iron, and azote, which are occasionally found in vegetables;

tables ; but as they are not common to all plants, they cannot be considered as essential to the constitution of vegetable matter.

But if the materials of which vegetables are composed are so few and simple, their organization is curious beyond any thing which the mineral world presents to our view. The parts of vegetables, which naturalists are accustomed to consider as distinct in their nature and functions, are six, the stem or trunk, the root, the leaf, the flower, the fruit, and the seed. In many vegetables the root appears nearly similar, in all its constituent parts and principles, to the stem or trunk, and indeed the one seems a continuation of the other ; which must be my apology for reversing in some degree the order of nature, and treating first of that part, which though it seems to proceed or spring immediately from the other, is yet the most perfect in its organization, and is in general of the greatest use and importance to man.

I. The stem or trunk, which includes also the branches, I might say all the more solid and substantial parts of a tree or plant, consists of three parts, the bark, the wood, and the pith.

1st. The bark is protected on the outside by a cuticle, epidermis, or scarf-skin, which consists sometimes of numerous layers, and differs in thickness in different plants. This skin or cuticle is an organized body, composed of very minute bladders, interspersed with longitudinal woody fibres, as in the nettle, thistle, and the generality of herbs. It contains also longitudinal vessels, and is visibly porous in some plants, and particularly the cane.

On removing the cuticle, the true bark appears, and may be considered as a congeries of pulp or cellular substance, in which are placed a number of vessels, as well as longitudinal fibres. The vessels of the bark are differently situated, and destined for various uses, in different plants. In the bark of the pine, for instance, the inmost are lymph-ducts, exceedingly minute; those nearest the surface are gum or resiniferous vessels, for the secretion of the turpentine, and these are so large as to be visible to the naked eye.

2d. The wood lies between the bark and the pith. Its substance is denser than that of the bark, and its structure more difficult to be understood. It is however generally supposed to consist of two substances, the parenchymatous or cellular, and the ligneous. The ligneous parts are no more than a congeries of old, dried lymph-ducts. Between the bark and the wood a new ring of these ducts is formed every year, which gradually loses its softness as the cold season approaches, and towards the middle of winter is condensed into a solid ring of wood. These annual rings, which are visible in most trees when cut transversely, serve as marks to determine their age. They seem to decrease in breadth, as the tree advances in age; and as they are found to be very unequal in size throughout, their breadth probably varies according as the season is favourable or otherwise.

The wood differs from the bark, not merely in the degree of hardness; its structure is essentially different, and the apparent conversion of bark into wood is entirely a deception. One striking difference

ference between the wood and the bark is, that the former is possessed of spiral vessels which run from one end of the tree to the other. From the great resemblance of these air-vessels to those of insects, they are supposed to be subservient to the same function. The stem of some plants is entirely hollow, partly, it is supposed, from these plants, which are generally of a quick growth, requiring a more than ordinary supply of air.

3d. The pith is situated in the center of the stem, and in young plants it is very abundant. It is said by some authors to consist of exactly the same substance as the parenchyma or cellular substance of the bark; and to be composed of small cells or bladders, generally of a circular figure, though in some plants, as the borage and thistle, they are angular. In most plants the pith gradually dies away as they approach to maturity; and in old trees it is almost entirely obliterated.

Such are the solid parts of plants; but to render their organization more clearly understood, in plate I. fig. 1. is the section of a branch of ash, cut transversely as it appears to the eye. Fig 2. is the same section magnified. A. A. the bark. B. B. B. an arched ring of sap-vessels next the cuticle. C. C. C. the cellular substance of the bark, with another arched row of sap-vessels. D. D. a circular line of lymph-ducts next the wood. E. E. the wood. F. the first year's growth. G. the second. H. the third. I. I. I. the true wood. K. K. the great air-vessels. L. L. the lesser air-vessels. M. M. M. parenchymatous insertions of the bark, represented by white rays. N. O. the pith.

The name of air-vessels, as was before remarked, has been given to certain tubes situated in the wood, leaves, and petals, but not in the bark of trees. They are formed by a number of small filaments, spirally rolled up so as to form a cavity in the middle, and are supposed to be the instruments of respiration in plants; but how this function is performed, is not clearly understood. Trees and shrubs only are possessed of air-vessels; and when a plant is placed under the exhausted receiver of an air-pump, the air only issues from the wood in which the air-vessels are situated.

There is reason to believe that the air's proper entrance to plants is through the cuticle, which is proved to be a vascular substance, since, when under an exhausted receiver, it issues directly through the cuticle. That the air is necessary to the sustenance of plants, appears from the experiments of Dr. Bell *. In the winter season he covered several young trees with varnish, leaving the tops of the branches only exposed to the air. They remained in this situation during the following summer, when some of them lived, though in a languid state; but those from which the air had been more accurately excluded, died without a single exception. To this proof the same author adds, that trees overgrown with moss have few leaves, weak shoots, and scarcely any fruit; and that it is the common practice of all judicious gardeners to strip the moss from the bark of aged trees, which by admitting

* See his excellent Thesis on the Physiology of Plants, Manch. Mem. vol. ii.

the air, generally restores them to vigour and fruitfulness.

II. The root, which fixes the plant to the earth, and is the chief source of its nourishment, differs much in different species of vegetables. All roots agree in being fibrous at their extremities, and it is by their fibres chiefly that they are fitted to draw nourishment. The root terminates upwards in the stem or trunk, which sustains the other parts of the vegetable. The internal structure of the root, or rather of its fibres, differs not very materially in general from that of the stem. It consists of a cuticle, bark, wood, and commonly of a small portion of pith; though there are some roots which have no pith at all, while there are others which have little or none at the extremities, but a considerable quantity near the top. The cuticle, in all roots at a certain age, is double; the cortical substance, or bark, differs greatly in its quantity and disposition in different plants. In trees it is thin; in carrots, on the contrary, it is one half of the semi-diameter of the root; and in dandelion it is nearly twice as thick as the woody part. The roots, as well as the trunk of plants, are furnished with a variety of vessels for the purpose of conveying and circulating air and the juices necessary to their nourishment.

In plate I. fig. 3. is a section of the root of wormwood, as it appears to the eye; and fig. 4. is the same magnified. A. A. the skin with its vessels. B. B. B. the bark. C. C. C. the lymph ducts of the bark. The other holes are small cells or sap-vessels. D. D. D. parenchymatous insertions from the

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bark.

bark. E. E. E. the rays of the wood, with the air-vessels.—This root has no pith.

III. The leaves are organs essential to the existence of plants. Trees perish when totally divested of them; and in general, when stript of any considerable proportion of their leaves, they do not shoot vigorously. The leaves are formed by the expansion of the vessels of the stalk into a net-work, which exhibits a beautiful appearance when the intermediate parenchymatous matter is consumed by putrefaction. Both surfaces of the leaf are covered with a membrane, which is a thin bark, continued from the scarf-skin of the stalk.

IV. The flower consists of four parts, the calyx, the corolla, the stamina, and the pistillum. The calyx or flower-cup is almost always of a green colour, and is that which surrounds and supports all the other parts of the flower. The corolla is of various colours, is variously shaped in different vegetables, and is that which constitutes the most conspicuous part of the flower. It sometimes consists of one continued substance, but more frequently of several portions, which are called petals. The stamina are supposed to be the male part of the flower. Linnæus defines them to be an entrail of the plant, designed for the preparation of the pollen. Each stamen consists of two parts; the filimentum or fine thread which supports the anthera, and the anthera itself, which contains within it the pollen, and when come to maturity discharges it for the impregnation of the germen. From the supposed function of the stamina, they afford the chief foundation of the distribution of the vegetable system
into

into classes. Such flowers as want this part are called female; such as have it, but want the pistillum, male; such as have them both, hermaphrodite; and such as have neither, neuter.

The pistillum or pointal is supposed to be the female part of the flower; it is defined by Linnaeus to be an entrail of the plant, designed for the reception of the pollen. It consists of three parts, the germen, the style, and the stigma. The germen is the rudiment of the fruit accompanying the flower, but not yet arrived at maturity. The style is the part which serves to elevate the stigma from the germen. The stigma is the summit of the pistillum, and is covered with a moisture for the breaking of the pollen.

The pericarpium or seed-vessel is the germen grown to maturity. Such are the constituent parts of the flower; they are however infinitely varied, and serve both to diversify the face of nature, and to interest and delight the curiosity of man. One curious fact it is necessary to notice, before I dismiss this branch of my subject, and that is, that every flower is perfectly formed many months before it makes its appearance. Thus the flowers which appear in this year are not properly the productions of this year: the mezereon flowers in January, but the flowers were completely formed in the bud in the preceding autumn. If the coats of the tulip-root also are carefully separated about the beginning of September, the nascent flower, which is to appear in the following spring, will be found in a small cell, formed by the innermost coats, as represented

mented in plate I. fig. 5. where the young flower appears towards the bottom of the root.

V. The fruit consists of nearly the same parts as are found in the stem; of a skin or cuticle, which is a production or continuation of the skin of the bark; of an outer parenchyma, which is the same substance continued from the bark, only that its vesicles are larger and more succulent or juicy. Next the core there is commonly an inner pulp or parenchyma; and the core is no more than a hard woody membrane, which incloses the seed. It is to be observed, however, that the organization of fruit is very various; in some the seeds are dispersed through the parenchymatous or pulpy substance; in some, instead of a core, we find a strong woody substance, inclosing the seed or kernel, which from its great hardness is termed the stone; in some, there are a number of seeds; and in others, only a single seed, inclosed in a large mass of parenchymatous matter.

VI. The seed is a deciduous part of a vegetable, containing the rudiment of a new one. The essence of the seed consists in the corculum or little heart, which is fastened to the cotyledones or lobes, and involved in them, and closely covered by its proper tunic. The corculum consists in the plumula, which is the vital speck of the future plant, extremely small in its dimensions, but increasing like a bud to infinity. The rostellum, however, must be included, which is the base of the plumula; it descends and strikes root, and is the part of the seed originally contiguous to the mother plant. It is commonly supposed, and with some reason, that

Fig. 1.

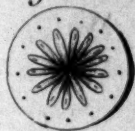


Fig. 2.

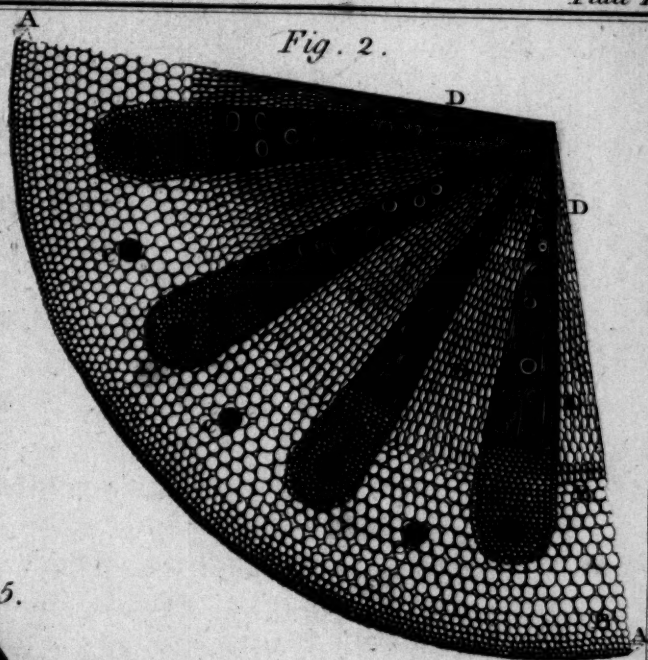


Fig. 5.

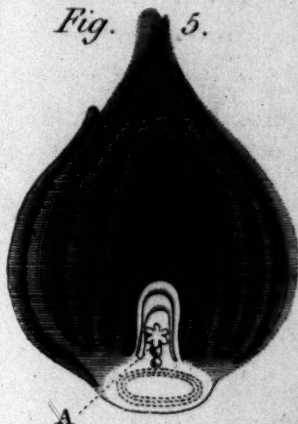
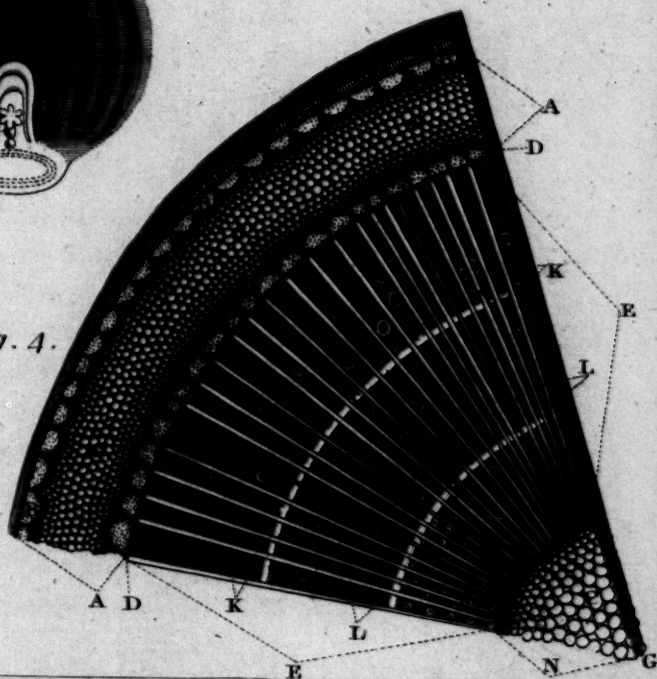
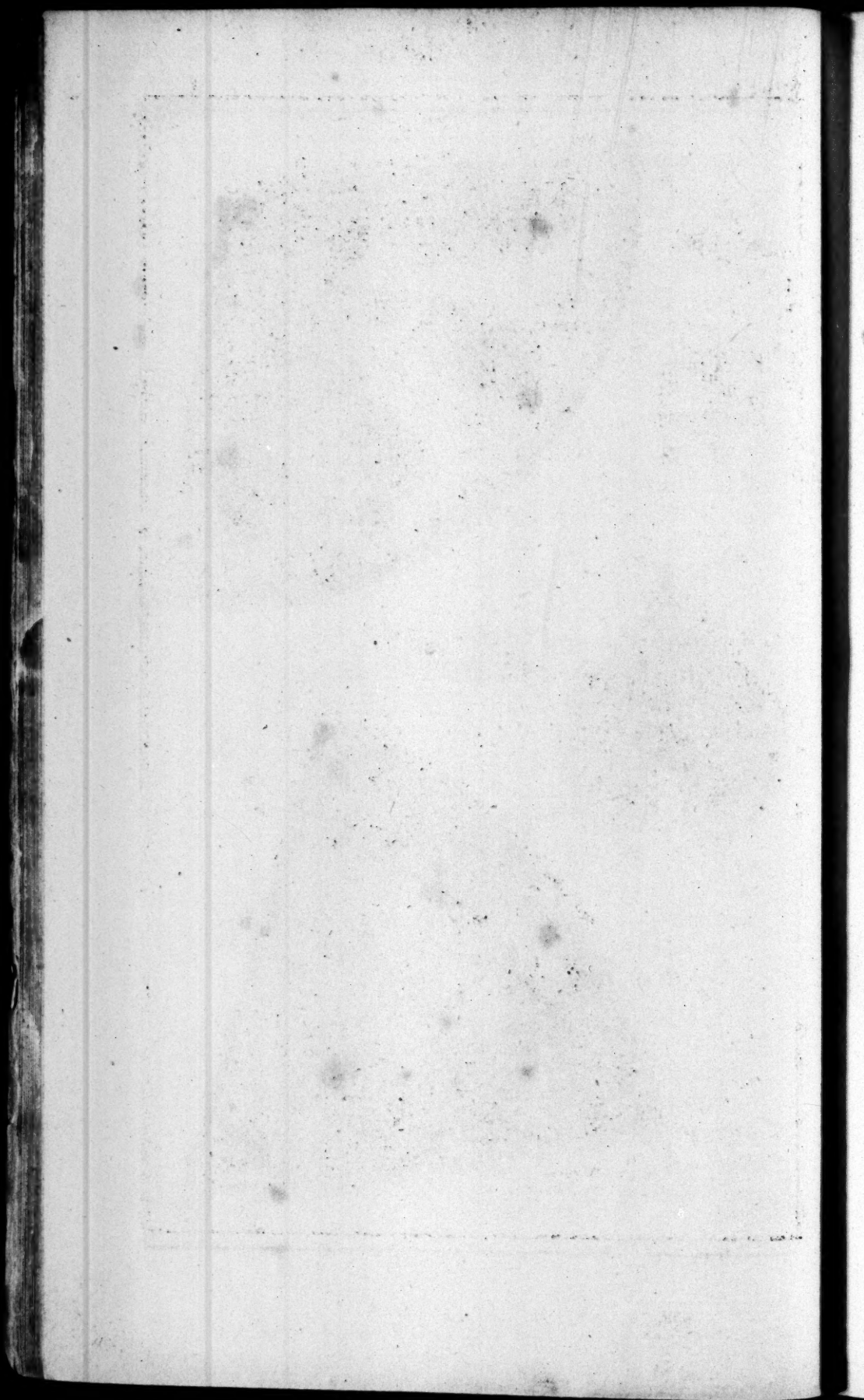


Fig. 3.

Fig. 4.





that the perfect plant, or at least all the organization which is requisite to a perfect plant, exists in the seed, surrounded by a quantity of farinaceous matter, which serves to absorb moisture, and to furnish nourishment to the corculum till its parts are sufficiently unfolded to draw support from the soil. A kidney-bean or lupine, when it has been soaked for some time in water, and begun to swell, is easily separated into its two lobes; and between these is displayed the nascent plant. The naked eye can easily discern the stem, and its connexion with the lobes. Through the lobes are diffused innumerable vessels, which immediately communicate with the embryo plant. On the external surface of the seed are absorbent vessels, which attract the moisture; by this moisture a degree of fermentation is produced, and thus a juice is prepared by a natural process in every respect proper for the nourishment of the plant in its first efforts to extend its tender frame. The plant in its infancy is almost a gelatinous substance, and increases and indurates by degrees; and I believe in general the hardness of wood bears a pretty exact proportion to the slowness with which a plant increases. That part of the stem which is next the root is the first which assumes the woody texture.

M. Bonnet, in order to ascertain how far the lobes of the seed were necessary to the growth and health of the corculum, detached them with great dexterity without a vital injury to the infant plant. Some French-beans treated in this manner, and sowed in a light soil, grew, but the consequence was, that not only the first leaves were much smaller,

smaller, but the plants were uniformly weaker in every part of their growth than others, which for the sake of comparison were sown at the same time without being mutilated. The seeds which were deprived of the lobes put forth fewer blossoms, and produced less seed. The seeds of mosses are naturally devoid of lobes. The first leaves which make their appearance, and which are called seminal, appear not less necessary to the perfection of the plant than the farinaceous lobes. If they happen to be broken off, the plant experiences a proportional loss of vigour.

It is matter of curious observation, that seed, thrown into the ground at random, should always come up in the proper direction. M. Dodart has offered an ingenious explanation of this fact, which consists in supposing that the rostellum contracts by humidity, and that the plumula on the contrary contracts by dryness. According to this idea, when a seed is put into the ground the wrong way, the rostellum, which then points upwards, contracts itself towards the part where there is most humidity, and therefore turns downwards. The plumula on the contrary pointing downwards, turns itself towards the part of the soil which is driest, and therefore rises towards the surface. This explanation, however, evidently rests on no better basis than conjecture.

Independent of the seed, there are two other methods by which plants are propagated, by slips and suckers; and many plants naturally make an effort to propagate themselves in this manner. The bulbous-rooted plants in general increase by off-sets.

When

When a tulip is first planted in the spring, the stem issues from the middle of the bulbous root; but when the tulip is taken up in the autumn, the stem no longer proceeds from the middle of the root, but seems attached to one side. The fact is, that the root which is taken up is not the same that was planted. The original root has decayed by having its substance absorbed for the nourishment of the blossom, and a new root has been provided for the future year.

C H A P. II.

FLUIDS OF VEGETABLES.

The Succus Communis or Sap.—Vessels for the Circulation of the Sap.—Succus Proprius; its Vessels and Course.—Bonnet's Experiments on the Nourishment of Plants.—Dr. Hales's Experiments on Fruit Trees.—Bonnet's on Flowers, &c.

THE fluids or juices of vegetables, says Dr. Bell, are of two kinds. ' The one is of the same nature in all the variety of vegetables: the other varies according to the different plants in which it exists. The former, which is called the *succus communis*, when collected early in the spring, from an incision made in the birch or vine, differs little from common water *. The latter, which is named the *succus proprius*, possesses various properties in various plants, and gives to each its sensible qualities. These two juices never mingle with each other in the tree, and the latter is found in the *vasa propria* only.

* It has, however, been alledged to contain a saccharine matter in some trees, as in the maple, &c. It has likewise been supposed to contain an acid. But, in various experiments which Dr. Bell made on it, he found nothing in it of either kind; and therefore, where such appearances have taken place, he supposed them to arise from an adventitious mixture of the sap, and the *succus proprius*.

' It

‘ It is not yet ascertained, whether the juices of plants are transmitted through vessels, or cellular substance. Each side of the question has had its advocates, who have supported their respective opinions with probable arguments: but it is to be regretted, that, on so interesting a subject, no conclusion can be formed from the actual dissection of vegetables. It however seems most probable, that all the fluids of plants are transmitted through vessels, for the following reasons.

1. The existence of *vasa propria*, and *vasa aëria*, is discoverable by the naked eye, and made still more manifest by the microscope. That *succus proprius* and air are contained in these is evident, and therefore analogy leads us to believe, that the *succus communis* is also contained in vessels. 2. Secretion, of which vegetables have undoubtedly the power, is in no instance, that we know of, performed without the action of vessels. 3. An experiment, made by Dr. Hales, seems clearly to prove, that the sap is contained within its own vessels, and does not fortuitously pervade every interstice of the plant. He fixed an instrument round the stem of a vine, by which its contractions and expansions could be accurately measured; but he found no difference in the circumference of the trunk, when the tree was full of sap, and when it was entirely without it, although the instrument employed was so nice, as to detect a variation of the hundredth part of a finger’s breadth. If the sap had been transmitted, without vessels, through the cellular substance, this, on the withdrawing of
of

of the sap, would have been compressed, and of course the stem of the tree would have contracted itself into a smaller compass *.

‘ Botanists have made many experiments to ascertain the course of the sap. Early in the spring, when the sap begins to flow, incisions have been made in the trunk and branches of trees, as far as the pith; and, in such cases, it has been constantly found, that a larger quantity of sap flowed from the superior, than from the inferior margin of the incision. This circumstance led to the opinion, that in the beginning of the spring, great quantities of moisture are absorbed by trees from the atmosphere, and hence the source of the abundance of sap †. But this conclusion is found to disagree with the phenomena of nature, from the two following experiments.

‘ 1. Incisions of various heights being made in the stem of several plants, their roots were immersed in a decoction of log-wood. The roots absorbed the coloured liquor, which at length began to flow from the superior, and not from the inferior, margins of the incisions; nor had the liquor extended

* To determine this question absolutely, it may seem, that the most certain and obvious method would be by injections, the great source of our knowledge of the anatomy of animals. They have been employed by Bonnet, Dr. Hope, and others, but they have failed. They rise a considerable way into plants, but as, in different cases, they take different courses, from this and other circumstances there is reason to believe, that their course, and that of the sap, are materially different from each other.

† Du Hamel and others.—See *Phys. des Arbres*, Tom. I. p. 67.

itself

extended itself much upwards, beyond the margin of the incision from which it was discharged.

‘ 2. In the season when the sap flows most abundantly, called the bleeding season, a deep cut was made into the branch of a growing vine, and the greatest quantity of sap was discharged from the upper margin of the incision: but a branch of the same tree, cut in the same manner, being inverted, the sap flowed most copiously from the other margin of the incision, which of course was now that next the root. On the other hand, many experiments may be brought to prove directly, that, in the bleeding season, the sap ascends from the roots towards the branches; the following however may suffice. 1. Early in the spring, when little or no sap had as yet entered the plant, Dr. Hope made a number of incisions, of different altitudes, into the root and stem of a birch. As the sap rose, it first flowed from the superior margin of the lowest incision, and then, in regular succession, from the upper margins of the other incisions, till at last it reached the highest. 2. If, in the beginning of the bleeding season, before the sap is found in the stem or branches, an incision is made in the root of a vine, a considerable flow of sap will follow the wound. 3. The quantity of sap is very generally proportioned to the humidity of the soil*.

‘ When

* It may still be asked, Why the sap flows most from the superior margin of each incision, supposing it to arise from the

When a portion of the bark and wood of the pine is cut from the stem, the *succus proprius* flows in considerable quantity both from the upper and under margin of the incision. Hence it occurred to botanists, that this juice might have little or no motion, and that its efflux from such an orifice might depend entirely on its being freed from the pressure of the bark and wood. But I cannot accede to this opinion: for although, in the beginning, the *succus proprius* flows from both margins of the incision, in a little while, as I have observed, it is discharged from the superior margin only. This observation in itself is not however decisive. For it may be supposed, that the liquor flows more copiously from the superior margin, because the pressure of the air is less upon it, than on the inferior, and because the liquor itself is disposed to fall downwards by its gravity, in the same manner as the *succus communis*. That I might put this matter out of doubt, I placed the branch of a pine in a horizontal position, and another branch I inverted, so that its branches were turned towards the earth. In these situations, I cut a portion of the bark and wood from each,

roots? The incision, it is said, hurts or destroys the energy of the sap-vessels for a considerable way below, whence the sap is not propelled upwards, against its own weight, and the pressure of the atmosphere now admitted. From the divided vessels, it passes by a lateral communication (for there are sap-vessels in every direction) into those undivided, and when it has got above the incision, it again passes laterally into the divided vessels; and falling downwards, from its own gravity, a want of continuity of vessels, and the diminished pressure of the atmosphere, it flows from the superior margin of the incision.

and,

and, in both instances, the *succus proprius* flowed only from those margins of the incisions which were farthest from the roots. Hence it appears clearly, that the course of this juice, in its vessels, is never from the roots towards the branches, but always in the contrary direction *.

M. Bonnet conceives that the nutrimental juices of vegetables pass during the day-time from the roots to the trunk by the ligneous fibres, assisted by the air-vessels, and are principally carried to the surface of the leaves, where a copious perspiration takes place. At the approach of night the heat no longer acting on the leaves and the air contained in the air-vessels, the sap returns towards the roots; at the same time that the humidity condensed on the inferior surfaces of the leaves, which by their inequalities are best fitted to retain it, is absorbed and conveyed through the branches to the trunk. In this manner he is of opinion that vegetables are nourished in the day-time by their roots, and in the night by their leaves.

The same philosopher wished to discover whether plants nourished by their leaves would live as long, and thrive as well, as others nourished by their roots. He plunged in small vessels, filled with water, plants of mercury, immersing the leaves of some and the roots of others. He left to each plant one or two sprigs, which were kept out of the water,

* From the experiment above recited, it appears, that the flow of the proper juice is not influenced in the same degree, as that of the sap, by an alteration in the posture of the vessels from which it issues. To what cause this is owing, does not clearly appear.

and which were only nourished by the part of the plant which was immersed. He rendered all these sprigs as equal and as much alike as possible. He left the plants in this situation for five or six weeks, at the end of which time he could observe no difference between the sprigs uniformly nourished by the leaves, and those nourished by the roots. He only remarked that the leaves plunged in water seemed to suffer a little more from the action of that fluid than the roots. M. Bonnet also buried the top of a willow-tree, leaving the roots above ground. The roots, being prevented from drying by a covering which did not entirely exclude the air, put forth leaves mixed with roots; the top, which was buried in the ground, produced roots, and the plant continued to live.

Dr. Hales, in his statical experiments, mentions several, in which he tried to change the natural flavour of fruits, and to communicate those of several spirituous liquors, and of different odoriferous infusions. With this intention he plunged in different liquors branches loaded with fruit; and left them there for some time, without being able to perceive that the taste of the fruits was in the least altered, whether the experiment was made upon them ripe or unripe. But he almost always perceived the smell of the liquors or infusions in the stalks of the leaves, and in the wood. He conjectures, with much probability, that the vessels near the fruit become so fine as not to admit the odoriferous particles.

M. Bonnet made experiments on flowers similar to those which Dr. Hales made on fruits. He chose

chose such flowers as have naturally little perfume, as the different species of French-beans. Stems with these flowers were immersed in tubes, some of which were filled with spirits of wine, others with Hungary-water, &c. In about twenty-four hours the flowers were faded, and they had already acquired in a very sensible degree the odours of the liquors which they had imbibed. The odour became much more remarkable a few days afterwards. M. Bonnet also found that the leaves of the apricot-tree acquired a sensible odour from the liquors into which branches of that tree were plunged.

C H A P. III.

FUNCTIONS OF VEGETABLES.

Perspiration of Plants.—Circulation of the Fluids in Plants.—Property in Plants of emitting vital Air; of decomposing Water.—Sensibility to the Sun's Light.—Cause of the Green Colour of Vegetables.—Bonnet's Experiments on Vegetable Perspiration.—Sexual System.—Growth and Nutriment of Vegetables.—Manures.—Principles of Agriculture.

THE leaves of plants have been not improperly compared with the lungs of animals. 'Plants as well as animals,' says an author whom I have already quoted with approbation, 'perspire, and in both cases this function is essential to health. By the experiments of Dr. Hales *, and M. Guettard †, it appears, that the perspirable matter of vegetables differs in no respect from pure water, excepting that it becomes rather sooner putrid. The quantity perspired varies, according to the extent of the surface from which it is emitted, the temperature of the air, the time of the day, and the humidity of the atmosphere. As the leaves form the greatest part of the surface, it is natural to suppose, that the quantity of

* Statical Essays, vol. i. p. 49.

† Mem. de l'Academie des Sciences, 1748.

these will very materially affect the quantity of the perspiration. Accordingly, the experiments of Dr. Hales have ascertained, that the perspiration of vegetables is increased or diminished, chiefly, in proportion to the increase or diminution of their foliage *. The degree of heat in which the plant was kept, according to the same author, varied the quantity of matter perspired; this being greater, in proportion to the greater heat of the surrounding atmosphere. The degree of light has likewise considerable influence in this respect: for Mr. Philip Miller's experiments prove, that plants uniformly perspire most in the forenoon, though the temperature of the air, in which they are placed, should be unvaried. M. Guettard likewise informs us, that a plant, exposed to the rays of the sun, has its perspiration increased to a much greater degree, than if it had been exposed to the same heat, under the shade. Finally, the perspiration of vegetables is increased in proportion as the atmosphere is dry, or in other words, diminished in proportion as the atmosphere is humid.'

Dr. Hales found that a sun-flower, weighing three pounds, perspired twenty-two ounces during twenty-four hours. Dr. Keil perspired thirty-one ounces in twenty-four hours. The quantity therefore perspired by the sun-flower was much greater, in proportion to its weight, than that perspired from the human body. Dr. Keil ate and drank four pounds ten ounces in twenty-four hours. Seven-

* Statical Essays, vol. i. p. 29.

24 *Odoriferous Exhalation from Plants.* [Book VIII.

teen times more nourishment was taken in by the root of the sun-flower, than was taken in by the man. If the perspiration of vegetables is checked, they speedily fade. It is checked from glutinous substances adhering to their surface; hence the advantage of washing them. The more healthy and vigorous the plant, the more copious the perspiration; though an excess, as well as a defect of it, seems prejudicial and even destructive to vegetables. It bears also a proportion to the quantity of leaves, these being the principal organs of perspiration.

The odoriferous exhalation of leaves and flowers forms an atmosphere around vegetables, which strikes our senses, and which the contact of a body on fire is sometimes capable of inflaming, as has been observed with regard to the *fraxinella*.

‘Some botanists,’ observes Dr. Bell, ‘have conceived, that plants, as well as animals, have a regular circulation of their fluids. Others think this very improbable. On both sides, recourse has been had to experiments; and from these, conclusions perfectly opposite have been deduced. When a ligature has been fixed round a tree, in such a manner that no juice could be transmitted through the bark, the tree has been found to thicken above the ligature; but below it, to continue of the same circumference. Hence some have concluded, that the sap ascends through the wood, and descends through the bark. Those who are of a contrary opinion have found, that, in certain cases, the juice ascends through the bark only: for when a portion of the wood has been cut out, and the bark exactly replaced, the growth of the
tree

tree has been found to go on unchanged : hence it is said, that the juice is transmitted equally through all parts of vegetables. The experiments adduced on each side of the question are just, but the reasonings on these, by each party, seem equally inconclusive. The analogy of animal nature appears to favour the opinion, that the juice rises through the wood only, and descends only through the bark ; but this analogy is not complete throughout. The arteries are not placed in the internal parts alone, nor the veins in the external, but they accompany each other through every part of their distribution. In vegetables, the sap rises *from* the roots, but the proper juice descends *towards* them ; in the descent of the juice, the wood acquires its growth, and absorption is a constant action of the leaves. These observations render it probable, that there is a circulation of the juices ; and if there is, the vessels which perform it, we may reasonably believe, accompany each other through every part of their course.

By what force the juices of plants are propelled in their circulation, remains yet one of the secrets of nature. It has been attributed to capillary attraction, but this cause seems inadequate to the effect ; nor is it possible on that principle to explain why the sap of the vine flows from an incision made in the spring, and not from one made in the summer. The capillary attraction ought not to be less powerful in the latter than in the former season ; indeed it ought to be more so, as the heat is greater. Besides, capillary tubes do not discharge their contents, when

when broken across ; but from the stem of a plant cut transversely, a large quantity of fluid is discharged. The more probable opinion is, that plants are endued with something of a vital power or energy, which impels the juices through the whole vascular system ; and this opinion is strengthened by an observation of Dr. Bell, which was the result of experiment, namely, that there are particular substances which increase the growth of plants, by acting as stimulants on their fibres.

The experiments of Dr. Priestley have sufficiently shewn that vegetables have the power of correcting bad air ; and Dr. Ingenhouz has proved that they have the faculty of producing vital air only when acted on by the rays of light. If a vegetable is immersed in water, and the rays of the sun directed on it, air-bubbles will be observed to collect on the leaves, and at length rise to the surface of the water. This appearance is most remarkable in the morning, as the leaves have not then been previously exhausted by the action of light. Vital air of a great degree of purity may be obtained in the summer time, by inverting a jar filled with water in such a manner as to receive the air-bubbles as they arise. All plants, however, do not emit this air with the same facility ; there are some which emit it the moment the rays of the sun act upon them, and this is the case with lavender. Some aquatic plants afford vital air with great facility, some more slowly, but none later than in eight or ten minutes, provided the sun's light is strong. The air is almost entirely furnished by the inferior surface of the leaves of trees ; herbaceous plants afford it from almost

almost the whole of their surface. The leaves afford more air when attached to the plant, than when gathered, and the quantity is greater, the fresher and sounder they are. Young leaves afford but a small quantity of vital air; those which are full grown afford more, and the more the greener they are. The epidermis, the bark, and petals do not afford it, and in general vital air proceeds only from those parts of plants which are of a green colour. Thus green corn and green fruits afford this air, but it is not produced by those which are ripe; and flowers in general render the air noxious. These facts may tend to explain the manner in which the light of the sun operates in maturing fruits, viz. by expelling the superfluous oxygen, and thus changing them from a harsh and sour, into a mild and sweet substance. Aquatic plants, and such as grow in moist places, are remarkable not only for affording a large quantity of vital air, but also for absorbing inflammable gas, and are therefore in all respects calculated for purifying the air of marshy situations. A very extraordinary power of absorbing inflammable air was observed in the willow by Dr. Priestley; and this fact seems connected with the rapid growth of that plant in marshy situations, where much inflammable air is produced. M. Sennabier found that plants yield much more vital air in distilled water impregnated with fixed air, than in simple distilled water.

It appears further, from the experiments of Dr. Priestley, that plants will bear a greater proportion of inflammable than of fixed air, and that vital air appeared generally injurious to plants. A sprig of
5 mint

28 *Pure Air produced by Plants in Water.* [Book VIII.]

mint growing in water, placed over a fermenting liquor, and of course exposed to fixed air, became quite dead in one day; a red rose became of a purple colour in twenty-four hours. Plants die very soon both in nitrous air, and in common air when saturated with it. Air appears uniformly to have been purified by healthy plants vegetating in it; but these experiments require great nicety, as the least degree of putrefaction will injure the air. The air contained in the bladders of marine plants was found considerably purer than common air.

Atmospheric air is restored, after being injured by respiration or combustion, by a plant vegetating in it. This restoration of air depends upon the vegetating state of the plant; for a number of mint-leaves fresh gathered being kept in air in which candles had burnt out, did not restore the air. Any plant will effect this purpose, but those of the quickest growth in the most expeditious manner.

That plants have a property of producing pure air from water is evident from an experiment of Dr. Priestley's. The green matter which is to be observed in water is doubtless a vegetable production. Water containing this green matter always afforded vital air in a large quantity, but water which had it not afforded none. It has been frequently observed that vegetables do not thrive in the dark. A receiver was therefore filled with water, and kept till it was in a state of giving air copiously; after this it was removed into a dark room, and from that time the production of air entirely ceased. When placed again in the sun, it
afforded

afforded no air till about ten days after, when it had more green matter, the former plants being probably all dead; and no air could be produced till new ones were formed.

From various experiments it appeared, that different animal and vegetable putrescent substances afforded a very copious pabulum for this green vegetable matter, which produced so freely the vital air; whence the philosophic author of this discovery is led to the following conclusions:—‘It is impossible,’ says he, ‘not to observe from these experiments the admirable provision in nature, to prevent or lessen the fatal effects of putrefaction, especially in hot countries, where the rays of the sun are most direct, and the heat most intense. Animal and vegetable substances, by simply putrefying, would necessarily taint great masses of air, and render it unfit for respiration, did not the same substances, putrefying in water, supply a most abundant pabulum for this wonderful vegetable substance, the seeds of which seem to exist throughout the atmosphere. By these means, instead of the atmosphere being corrupted, a large quantity of the purest air is continually thrown into it. By the same means also, stagnant waters are rendered much less offensive and unwholesome than they would otherwise be. That froth which we observe on the surface of such waters, and which is apt to excite disgust, generally consists of the purest vital air, supplied by aquatic plants. When the sun shines, this air may be observed to issue from them. Even when animal and vegetable substances putrefy in air, as they have generally some moisture in them, various other vegetable productions, in the
form

form of mold, &c. find a proper nutriment in them, and by converting a considerable part of the noxious effluvia into their own substance, arrest it in its progress to corrupt the atmosphere.

The same vegetables which afford vital air very plentifully in the light of the sun, afford in the shade air less pure than that of the atmosphere. This striking effect of light on vegetables is a strong argument in favour of the opinion, that the motion of the juices of vegetables is performed by vessels, which, like those of animals, possess irritability, and are excited to action by stimulating substances.

The effect of vegetation in producing the vital air, which was afforded in the preceding experiments, seemed in some measure dubious to Sir Benjamin Thompson, who extracted vital air, by immersing in water a variety of substances, as raw silk, cotton, wool, eider-down, hare's fur, sheep's wool, ravellings of linen, and human hair—as related in a former book. He was led, from the result of these trials, to suspect that the pure air was merely separated from the water, and that any substance which would act by a capillary attraction, so as to separate the component parts of the water, would effect the production of pure air. He therefore procured a quantity of spun glass, which consists of minute tubes, which he immersed in water, but the quantity of pure air produced was very trifling. Hence he concludes, that there is something in those substances which operates in producing pure air, and that it is not merely a mechanical separation of the component parts of water.

The

The light of lamps produced the same effect as the sun's light, air in great quantities was produced, and perfectly pure. Vegetables will also, with any strong light, produce vital air as well as with the light of the sun. The air from silk was much superior to that from vegetables.

Plants have a remarkable sensibility to light; they unfold their flowers to the sun, they follow his course by turning on their stems, and are closed as soon as he disappears. Vegetables placed in rooms where they receive light only in one direction always extend themselves that way. If they receive light in two directions, they direct their course towards the strongest. Trees growing in thick forests, where they only receive light from above, direct their shoots almost invariably upwards, and therefore become much taller and less spreading than such as stand single. This affection for light seems to explain the upright growth of vegetables, a curious phenomenon, too common to be much attended to. It has been ascertained by repeated experiments, that the green colour of plants is entirely owing to light; for plants reared in the dark are well known to be perfectly white.

If we take a succulent plant, and express its juice, the liquor appears at first uniformly green; but allow it to stand, and the green colour separates from the watery fluid, and falls to the bottom in a sediment. If we collect this sediment it will be found to be of an oily nature, for it does not dissolve in water, but it will in spirits of wine, or oil, to which it imparts a green colour. As the sun produces the green colour in plants, and as this re-

fides

32 *Cause of the Green Colour of Plants.* [Book VIII.]

rides in an oily matter, it was formerly concluded that light furnishes the oily matter of vegetables, and that it effects this by furnishing the principle of inflammability. The new chemical doctrines, however, afford a much more satisfactory explanation of the effect of the sun's rays in producing the oily matter in vegetables. Vegetable matter consists in general of carbon, hydrogen and oxygen; the sun's rays produce a disengagement of the latter principle in the form of vital air, and the two former are the constituent principles of oil.

M. Bonnet made a series of experiments in order to ascertain whether the superior or the inferior surfaces of leaves have a greater share in performing perspiration. From the trials which he made, he concludes that the inferior surface of the leaf is in general by far the most active in this respect, though in one or two species of vegetables this difference was much less remarkable. The mallow was the only vegetable the leaves of which perspired more by the upper than the inferior surface. The method which he employed to ascertain the comparative effect of the two surfaces was to cover first one and then the other surface with oil. The leaves were then immersed in tubes filled with water, and the quantity of the perspired matter was measured by the length of the tube emptied in a given time. The oil, by stopping up the pores, prevented perspiration from the surface to which it was applied. Some large leaves of the white mulberry-tree being kept suspended on water with their upper surfaces in contact with the fluid, faded in five days; some leaves of the same tree, being placed in a similar situation,

situation, but with the inferior surface touching the water, were preserved green for nearly six months.

The sexual system has been the fashionable system of botany for many years. It is well known that the palm is of that class of vegetables which has flowers of different sexes on different trees. The peasants in the Levant, whether acquainted with this fact, or whether directed to the practice by accident alone, have been accustomed to break branches from the male palm while in flower, and attach them to the female plant, which they find to be constantly productive of an abundant crop. This fact has also been proved by a most decisive experiment of M. Gleditsch. There was in the royal garden at Berlin a beautiful palm-tree, a female plant, which, however, though twenty-five years old, had been always barren. There was another palm at Leipzig of the male kind, which blossomed every year. This ingenious botanist undertook to fecundate the palm at Berlin from that at Leipzig, and had some of the blossoms conveyed by the post. The consequence was, that he produced that season excellent dates; and the experiment, prosecuted with some variation for several succeeding years, was attended with the same success*.

It has been said, that the pollen was destined for the impregnation of the germen. This is performed in the following manner. The antheræ, which at the first opening of the flower are whole, burst soon after, and discharge the pollen. Being dispersed about the flower, part of the pollen

* Bonnet Contemp. p. 6.

lodges on the surface of the stigma, where it is detained by the moisture with which that part is covered. Each single grain or atom of the pollen has been observed by the microscope to burst in this fluid, and is supposed to discharge something which impregnates the germen below: what the substance is which is so discharged, and whether it actually passes through the style into the germen, seems yet undetermined, from the great difficulty of observing such minute parts and operations. In some vegetables, the stamina move towards the pistillum; and a very evident motion of them is observed in the flowers of the common berberry, on touching them with the point of a pin.

The NOURISHMENT of vegetables, as it is so intimately connected with the important science of agriculture, has deservedly attracted considerable attention. Mr. Boyle dried in an oven a quantity of earth proper for vegetation, and, after carefully weighing it, planted in it the seed of a gourd; he watered it with pure rain-water, and it produced a plant, which weighed fourteen pounds, though the earth had suffered no sensible diminution.

A willow-tree was planted by Van Helmont, in a pot, containing 100 pounds of earth. This was in general watered with distilled water, or sometimes with rain-water, which appeared perfectly pure. The vessel containing the plant was covered in such a manner as totally to exclude the entrance of all solid matter. At the end of five years, upon taking out the plant, he found it to have increased in weight not less than 119 pounds, though the earth

earth had lost only two ounces of its original weight.

These experiments would admit of some doubt, and must have remained in a great measure inexplicable, but for the experiments of Mr. Cavendish, and the facts related by Dr. Priestley, which place it beyond a doubt, that vegetables have a power of decomposing water, and converting it, with what they derive from the atmosphere, into almost all the different matters found to exist in their substance. For the products of wood in distillation, I must refer the reader to what has been advanced in the chapter on carbon, or the carbonaceous principle.

All the proper juices of vegetables depend on the organization, as is evident from the operation of grafting. From the materials of simple water and air, are produced those wonderful diversities of peculiar juices and fruits, which the vegetable world affords; and the immense variety of tastes, smells, &c. In the same vegetable what a variety is found! The bark is different in taste from the wood, the peculiar juices have something different from them both, and the pith of some plants affords a matter which could not have been expected from their exterior qualities. The root is often different from the stem, and the fruit from both, in all their sensible qualities.

In whatever way the nourishment of vegetables is received, it may fairly be said to consist principally of water. I am inclined to believe, however, that calcareous earth, in small portions, may enter into the composition of at least many vegetables; since animals which exist entirely on

vegetable food are found to have in their solid parts, the bones for instance, a considerable portion of this substance; though it must be confessed, that chemical analysis, as far as it has hitherto gone, does not warrant us in supposing calcareous earth to be an essential constituent of all vegetable matter. It may be said further, that on some occasions the addition of other matters, as of different kinds of manure, adds greatly to the growth of vegetables; but in whatever degree a rich soil or dung may add to the luxuriance of growth, other facts seem to prove that it is not essential to vegetation. It is well known that many herbs flourish in pure water, and that pear, plum, and cherry-trees, planted in pure moss, have arrived at such perfection as to produce good fruit *.

Different theories have been advanced, to account for the operation of manures in promoting the growth of vegetables, none of which seem altogether satisfactory. The common opinion is, that the substances employed as manures are the food of plants, and are absorbed by their roots. This hypothesis may be true to a certain extent, when

* It is but fair to insert the following fact, which seems to favour the necessity of carbonic matter to the growth and increase of at least some species of vegetables.

“ M. Ruchert is persuaded that earth and water, in proper proportions, form the sole nutriment of plants; but M. Giobert has clearly shewn the contrary; for, having mixed pure earth of alum, silice, calcareous earth, and magnesia, in various proportions, and moistened them with water, he found that no grain would grow in them; but when they were moistened with water from a dunghill, corn grew in them prosperously. Hence the necessity of the carbonic principle is apparent.”—*Kirwan on Manures*, p. 42.

applied

applied to some manures, but cannot be true with regard to them all; for it is well known, that not only chalk and lime, but even flints, are very beneficial to some soils. Another opinion is, that manures act by bringing soils to such a consistence as is favourable to the growth of the roots of vegetables, and to the affording of them water in a proper quantity. A third opinion is, that manures act as stimuli on the roots of vegetables, and thus excite them to more vigorous action. Some authors think that manures act as solvents on matters previously contained in the soil, and thus fit them for entering the roots of plants; and others, that they act chemically, by forming combinations which are favourable to vegetation. Which of these hypotheses is best founded, it is difficult to determine; but it does not seem unlikely that they may be all true to a certain extent.

When we attempt to discover the component principles of the objects around us, and the sources whence they are supported, we are lost in the greatness and diversity of the scenes presented to us. We see animals nourished by vegetables, vegetables apparently by the remains of animals, and fossils composed of the relics of both these kingdoms. It seems certain, however, that vegetables preceded animals. A seed of moss lodging in a crevice of a bare rock is nourished by the atmosphere, and the moisture afforded by the rains and dews. It comes to perfection, and sheds its seeds in the mouldering remains of its own substance. Its offspring do the same, till a crust of vegetable mould is formed sufficiently thick for the support

of grafs and other vegetables of the same growth. The same process going forward, shrubs, and lastly the largest trees, may find a firm support on the once barren rock, and brave the efforts of the tempest.

From the advantages derived from a change of crops in agriculture, it has been supposed that different vegetables derive different kinds of nourishment from the same soil, selecting what is best adapted to their own support, and leaving a supply of nourishment of another kind for vegetables of a different species. Was this, however, the case, vegetables would not so much impede each other's growth when placed near together. And in the operation of grafting, we have a clear proof, that the juices received by the root of one species of tree may, by the organization of the inserted twig, be subservient to the growth of leaves, flowers, and fruit of a different kind. The advantage derived from a change of crops may be better explained on other principles: some plants extend their roots horizontally on the surface of the soil, others strike them downwards to a considerable depth. Some plants are found to bind or harden the soil, others to loosen it. Thus, for example, wheat and rye-grass render a soil stiff, while pulse, clover and turnips pulverize it. By varying the crops, therefore, the soil is preserved in a middle state, between too much stiffness and too much friability. Nor is this the only good effect arising from this difference of roots. From this circumstance some vegetables draw their nourishment from the surface of the earth, while others derive

it partly from a greater depth. So that by a change of crops, a larger portion of the soil is made to contribute to the nourishment of plants than could have been effected by the cultivation of any single species. One other advantage to be derived from a change of crops, is this: some plants extract almost the whole of their nourishment from the soil; and this is particularly the case with those which are most valuable, and which contain the greatest quantity of solid matter. By the repetition of such crops, however, the soil is found to become too much exhausted. There are other plants which derive a large proportion of their nourishment from the air; by such therefore the soil will be much less exhausted, and under a crop of them will be in some measure at rest. The good effects of a change of crops may therefore be sufficiently explained, without supposing that each particular species of vegetables is nourished by a different kind of food. This opinion is also necessarily attended with two great difficulties: one is, that there exists in every soil as many distinct kinds of nourishment, as there are species of plants capable of growing in that soil; the other, that plants are endued with the faculty of discerning and selecting, from all these kinds, their own proper nourishment. The former of these suppositions is too absurd to merit the least attention, and the latter has been disproved by actual experiment, since plants are not able to prevent their roots from absorbing such matters as prove poisonous to them. Other writers, however, have been more moderate, and though they have rejected the idea of specific nourishment in general, have ne-

vertheless imagined that the hypothesis might be well founded with respect to particular species of vegetables. This they infer from the existence of specific manures, as soot for faintfoin, ashes for white clover, and some others. It does not seem possible, however, to draw a line of distinction; and if we reject the idea of a specific nourishment in general, we cannot admit it in particular instances.

In order to discover whether plants have an actual power of distinguishing matters presented to their roots, a friend, who assisted me in compiling this part of the work, made, among others, the following experiment.

A vigorous plant of mint was placed in a two-ounce phial, filled with filtrated well-water, to which were added four drops of a moderately strong solution of sal martis. On examining the plant the following day, no other effect was observed, than that the very tips of the radicles were withered and black. Four more drops of the solution were now added. On the third day the appearances were the same; and no new change taking place on the fourth, twelve more drops of the solution were added. On the fifth day the roots appeared of a yellowish green colour, and the top drooped very much. The larger leaves were pretty much withered and blackened. The absorption of the water appeared to be in some measure impeded, but not entirely prevented. On the sixth day the whole plant was withering very fast; the roots became of a dark olive-green colour, and the larger leaves were become very black, especially the foot-stalks and

and the projecting fibres. On the seventh day the blackness had made still further progress, and the plant was dead. A sufficient proof that some of the iron was absorbed by the plant, may be drawn from the following circumstance—its leaves when macerated in distilled water, produced a black colour with galls. The leaves of a plant of mint, which had been nourished by water alone, when tried by the same test, produced no colour whatever. Trifling as this experiment may appear, it proves two points; that plants have not the power of rejecting even injurious matters when presented to their roots; and that other matters besides water and air are capable of being absorbed by them.

Agriculture seems yet to be nearly in its infancy, and even the benefit produced by the common custom of letting lands lie fallow, has not yet been satisfactorily explained. Something may no doubt be attributed to the destruction of weeds, but more probably to some change produced in the soil by its being exposed to the action of the sun and air. The management of nitre-beds may tend to throw some light on this subject. These are composed of calcareous earth and dung cemented together. After being exposed for some months to the air, they are found to contain a quantity of nitrous acid, which, uniting to the calcareous earth, forms a kind of salt, which is extracted by lixiviation. Now calcareous earth and dung are two of the most powerful kinds of manure, and it does not seem improbable that their fertilizing powers may be in some manner connected with their property of affording nitrous acid.

C H A P. IV.

VEGETABLE SUBSTANCES.

Of the most remarkable Vegetable Productions.—Vegetable Oxyds.—Vegetable Acids.—Other essential Salts of Vegetables.

IT has been already remarked, that the simple component principles, which are essential to the formation of vegetable matter, are but three in number, namely, carbon, hydrogen, and oxygen. From the various proportions in which these ingredients are combined, results almost all the variety of vegetable matters which fall under our notice. Sugar, mucus (under which term I include the different kinds of gums, and starch) are vegetable oxyds, having hydrogen and charcoal combined, in different proportions, as their radicals or bases, and united with oxygen, so as to bring them to the state of oxyds. From the state of oxyds they are capable of being changed into that of acids, by the addition of more oxygen; and according to the degrees of oxygenation, and the proportion of hydrogen and charcoal in their bases, they form the several kinds of vegetable acids. On the other hand, gum by being deprived of oxygen is capable of affording oil. M. Woulfe has found that a pound of gum arabic distilled with a quarter of a pound

pound of vegetable alkali, furnishes a considerable quantity of oil. The liquor which rises along with it is not at all acid; therefore the acid of the gum remains united with the alkali. Honey afforded copiously an oil, when submitted to the same process.

The following are all the vegetable acids hitherto known,

1. Acetous acid, or vinegar.¹
2. Oxalic acid, or that of sorrel and sugar.
3. Tartarous acid.
4. Pyro *, or empyreumatic, tartarous acid.
5. Citric acid, or that of lemons.
6. Malic acid, or that of apples.
7. Pyro-mucous acid.
8. Pyro-ligneous acid.
9. Gallic acid, or that of galls.
10. Benzoic acid, or that of Benjamin.
11. Camphoric acid.
12. Succinic acid, or that of amber.

Nitrous acid, repeatedly distilled with gums, mucilages and sugar, is decomposed, the azote in part escapes, and the oxygen uniting with the inflammable matter of these substances, produces the acid of sugar. By a continuation of the process, however, the hydrogen and charcoal of the mucilaginous matters are separated; the charcoal, combining with the oxygen, forms carbonic acid gas, and the hydrogen either escapes in the state of inflammable air, or, attracting part of the oxygen, forms water. From this view of the subject, toge-

* Pyro from the Greek *πυρ* (fire) means any thing prepared or extracted by fire.—Empyreumatic has the same etymology and meaning.

ther with other facts, it has been inferred, that a greater or less proportion of vital air, united with the other two general principles of vegetables, hydrogen and charcoal, produces all the various acids of vegetables. Thus tartar is said to have been converted into the acid of apples, by treatment with nitrous acid. The acid of apples, by the continuance of the operation, becomes converted into acid of sugar, or acid of sorrel, which are the same thing. The same process further continued, affords vinegar. Hence it should seem that according to the greater progress of the operation of combustion, or the combination of vital air with the bases, the acids of tartar, of apples or unripe fruit, of sorrel or sugar, of vinegar, and lastly of charcoal, are produced. In this order of proceeding, the acids become more and more perfect, and less easily decomposable; and it probably proceeds from this cause, that the reverse of these processes could never be completely accomplished.

Professor Murray, of Gottingen, has assured us, that he has obtained acid of sugar by repeated distillations and congelation, without using nitrous acid. Abbè Fontana obtained an acid perfectly like that of sugar from all the gums and resins. Mr. Watt of Birmingham, when making some experiments relative to ink, observed a number of particles floating in the fluid, which had the shape of crystals of the saccharine acid, and upon examination were found to be really such; and, conducting the process in the usual way with the nitrous acid, he found that astringent vegetable matters contain the
acid

acid of sugar in greater abundance than that substance from which it derives its name.

These saline matters are called essential salts of vegetables. There are some others which are also called essential salts, but are not peculiar to vegetables. Such as the fixed vegetable alkali, which may be extracted by incineration from plants in general, and the fixed fossil alkali, which is only extracted from marine plants. Several neutral salts may also be extracted from particular vegetables: as vitriolated tartar from millefoil, and from astringent and aromatic plants; Glauber's salt from tamarisk; common salt and muriat of pot-ash from marine plants. Many other salts will doubtless be found, when a greater number of plants shall be accurately analysed.

CHAP. V.

OF THE MORE SIMPLE VEGETABLE
COMPOUNDS.

Gum.—*Gum Arabic.*—*Gum Tragacanth.*—*Common European Gum*—*Sugar; obtained from most Vegetables.*—*Process of making Sugar.*—*Manna.*—*Fat, or expressed Oils.*—*Chocolate.*—*Vegetable Wax.*—*Analysis of Olive Oil.*—*Essential Oils.*—*Of Cinnamon.*—*Of Balm, Peppermint and Wormwood.*—*Of Lavender.*—*Of Roses.*—*Of Aniseed.*—*Of Parsley.*—*Of Camomile.*—*Of Sassafras and Carraway.*—*Of Nutmeg, Pepper and Mace.*—*Balsams.*—*Balsam of Tolu.*—*Benzoin and Storax.*—*Camphor, Resins.*—*Gum Copal.*—*Catchouc or elastic Gum.*—*Fecula.*—*Briony.*—*Potatoes.*—*Sago.*—*Salep.*—*Farina or Flour.*—*Gluten.*—*Starch.*—*Saccharine Matter of Wheat.*—*Bread.*—*Colouring Matters of Vegetables.*—*Principles of the Art of Dying.*—*Arnotto.*—*Bastard Saffron.*—*Archil.*—*Indigo.*—*Alkanet Root.*—*Luteola.*—*Madder.*—*Walnut.*—*Alder.*—*Sumach, &c.*—*Galls.*—*Lakes.*

THERE are certain compound substances, which are formed by the process of vegetation, and may be obtained without the application of any greater heat than that of boiling water, or the action of any other solvents, than water and ardent spirit. These substances may be referred to the following heads:—1. Gum. 2. Sugar. 3. Fat Oils. 4. Essential Oils. 5. Balsams. 6. Camphor. 7. Resin. 8. Pure fecula of vegetables. 9. Farina. 10. Vegetable colouring matters.

I. GUM.

I. GUM.—Its characters, when in its purest state, are those of a substance inodorous, insipid, generally solid, of more or less transparency, with sometimes a slight tinge of colour, generally yellow; easily soluble in water into a viscid liquor, called mucilage, in which state it originally existed in the vegetable; not acted on by spirit of wine or oils; not volatile in the heat of boiling water, nor fusible in any heat, but subject to the same changes as other vegetable matter.

Gum, in its dry and solid state, is not in the least acted on by oils, but mucilage manifests a considerable disposition to unite with them. Gum is not a solvent of resinous or balsamic matter; this matter will, however, be dissolved in water, in consequence of being added to gum, especially by the assistance of agitation. Thus oils and balsams may in many cases be combined with water, and remain combined with it, forming a milky solution, particularly if the quantity of gum is considerable. This kind of combination is very frequent in plants. There are many in which oil and gum are naturally united. The useful juice of the poppy is of this kind, and from such compounds gum-resins are obtained, by the evaporation of their watry parts. They have still solubility in water, though the gum is the part chiefly dissolved; the resinous part is either left in its concrete state, or being merely suspended, and not dissolved, its particles are interposed between those of the gum and water, and occasion a degree of opacity. Such substances also in their solid state as consist of a mixture of gum and resin are always opaque, while the
pure

pure gums and pure resins have more or less of transparency.

Gum is very abundant in the vegetable kingdom; it is found in a great number of roots; the young shoots and young leaves contain it in large quantities, and its presence may be known by its viscous and adhesive quality, when these parts are crushed between the fingers. Gum is usually obtained by wounding the bark of particular trees. It is observable, that saccharine fruits, when sour and unripe, are found to contain gum and an acid; whence it seems not unfair to conclude, that saccharine matter is formed of these materials, operated on by the process of vegetation.

The most common gums are—1. Gum Arabic, which flows from the acacia in Egypt and Arabia, and is of the same nature with gum Senegal, which is sometimes sold instead of it. 2. Gum tragacanth, which is obtained from a thorny bush, growing in Crete, Asia, and Greece. 3. The gum which flows from certain trees growing in this country, particularly apricot and plum-trees. The essential characters of all these gums are the same, but gum tragacanth is by far the most powerful in producing a thick and tenacious mucilage.

II. SUGAR.—The mixed and various properties of this substance, have rendered chemists very doubtful to what class of bodies it ought to be referred. By some it has been called inflammable, by others saline, and by others it has been classed among gummy and mucilaginous matters. Sugar is soluble, both in water and ardent spirit. It is more inflammable than gums, and has not been proved

proved to contain any salt ready formed, except some fixed alkali. It is the only principle the presence of which enables fluids to take on the vinous fermentation.

Saccharine matter is found in a great number of vegetables; such as the maple, the birch, the red beet, the parsnip, the grape, farinaceous grain, potatoes: Margraff indeed extracted it from most vegetables; and it is well known that honey is a saccharine matter, collected by the instinct of the bee from an infinite variety of plants, but principally from flowers. The *arundo saccharifera* or sugar-cane contains this matter however in larger quantities, and affords it more readily, than any other plant. The ripe canes are twice crushed between iron cylinders, by which they are squeezed completely dry, and sometimes even reduced to powder. The cane juice or melasses is received in a leaden bed, and thence conveyed into a vessel called the receiver; thence it runs to the boiling-house, where it is received into a copper pan or caldron, which is called a clarifier. Of these there are generally three, and their dimensions are determined by the extent of the owner's plantation. Methods of quick boiling are indispensably necessary, as the purest cane juice will not remain twenty minutes in the receiver, without fermenting and becoming tainted. As soon as the stream from the receiver has filled the boiler or clarifier with fresh liquor, and the fire is lighted, the temper, which is generally Bristol white lime in powder, is stirred into it. This is done in order to neutralize the superabundant acid, to get rid of which is the great difficulty in making sugar. As

the force of the fire increases, a scum is thrown up, which proceeds from the gummy matter of the cane, with some of the oil, and such matters as are entangled in the mucilage. The heat is now suffered to increase gradually, till it approaches to that of boiling water; but it must by no means be suffered to boil. When the scum begins to rise into blisters, and break into white froth, which generally appears in about forty minutes, it is known to be sufficiently heated. The fire is then extinguished, and, if circumstances will admit, the liquor is left a full hour undisturbed. The liquor is now carefully drawn off, so as to leave the scum, and conveyed by a gutter to the evaporating boiler; and if produced from good materials, and well managed, it will appear almost transparent. In this vessel it is suffered to boil, and the scum as it rises is continually taken off, till the liquor becomes finer, somewhat thicker, and almost of the colour of Madeira wine. Being transferred to a smaller copper, the boiling and scumming are continued; and if the liquor is not so clear as might be expected, lime-water is added, which thins the mixture, so as to suffer the impurities to rise more readily to the surface. When, in consequence of such scumming and evaporation, the liquor is so reduced that it can be contained in the third copper, it is laded into it, and so on to the last copper, which is called the *teache*. This arrangement supposes four coppers, besides the three clarifiers.

In the *teache* the liquor undergoes another evaporation, till it is supposed to be boiled enough to be removed from the fire.

The cooler (of which there are generally six) is a shallow wooden vessel, about eleven inches deep, seven feet in length, and from five to six feet wide. A cooler of this kind holds a hoghead of sugar. Here the sugar grains, that is, as it cools it runs into a coarse irregular mass of imperfect crystals, separating itself from the melasses. From the cooler it is taken to the curing-house, where the melasses drains from it. When it is cooled so that the finger may be plunged into it without injury, it is poured into barrels, placed over certain cisterns, and pierced at the bottom with many holes, imperfectly stopped with the stalk of a plantain leaf, through which the syrup drains. In the space of three weeks the sugar becomes tolerably dry and fair. It is then said to be cured, and the process is finished. The sugar thus obtained is called *muscovado*, and is the raw material whence the British sugar-bakers chiefly make their loaf or refined lump. The juice of the sugar-cane contains a superabundance of acid, which prevents the dry concretion. In order to get rid of this, they employ lime-water, as the saccharine acid is separated by its means from every other combination. The lime powerfully attracting the acid when united with it, forms an insoluble salt, which either falls to the bottom or mixes with the scum. Many persons have supposed that a portion of the lime remains mixed with the sugar; but Bergman assures us, that if the purification is properly conducted, the nature of the ingredients, the circumstances of the operation, and finally the most accurate analysis, abundantly shew, that there is not the smallest trace of lime

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remaining.

remaining. Good sugar dissolves totally in distilled water, which could not possibly be the case if there was present any lime, either in a separate state or united with the saccharine acid.

There is another sort of sugar, which is much used, and which in England passes by the name of Lisbon sugar, but which in the West Indies is called *clayed* sugar; the process for making it is as follows:—A quantity of sugar from the cooler is put into conical pots or pans, with the point downwards, having a hole about half an inch in diameter at bottom, for the melasses to drain through, but which is at first stopped with a plug. As soon as the sugar in these pots is cool, and becomes a fixed body, which is known by the middle of the top falling in, the plug is taken out, and the pot placed over a large jar, intended to receive the syrup which flows through. In this state it is left as long as the melasses continues to drop, when a stratum of moistened clay is spread on the sugar. The water gradually draining from the clay, dilutes the melasses, in consequence of which more of it comes away from the sugar, which becomes whiter and finer. A second covering of clay is put on when the first is dry, and water is again suffered to filter through, after which the loaves are carried to an oven to dry. At the end of eight or ten days these loaves are broken, and the powdered sugar is conveyed to Europe.

Certain juices which flow out of plants are of a saccharine nature; such is manna, which is produced by the pine, the fir, the oak, the maple, the juniper, the fig, the willow, &c.; but the ash,
the

the larch, and the alhagi afford it in the largest quantities. Robel, Rondelet, and others, have observed at Montpellier, upon the olive-trees, a kind of manna, to which they have given the name of *oeliomeli*. Tournefort collected it from the same trees at Aix and Toulon. The ash, which is very abundant in Calabria and Sicily, affords the manna of commerce: it flows spontaneously from these trees, but is much more abundantly collected by making incisions in the bark. That which is procured by introducing chips of wood or small sticks into artificial apertures, forms a kind of stalactites, perforated within, and called manna in the tear. Manna in flakes flows from the bark, and contains some impurities. Manna affords, by treatment with the nitrous acid, the same acid as is obtained from sugar.

III. FAT OILS are not emitted from the surface of vegetables, but are obtained by pressure from their emulsive seeds or kernels. They feel smooth to the touch, are generally, when recent, without smell or taste, and are insoluble in water. They are not volatilized but by a heat considerably superior to that of boiling water, and do not take fire till sufficiently heated to be volatilized. When they are burned on the wick of a lamp, small portions are successively brought to its extremity, and being there volatilized, undergo inflammation. Most fat oils are fluid, and require a considerable degree of cold to congeal them; others become solid by a very slight degree of cold; and others again are almost always solid: these last are called butters.

Such are those of the cacao-nut, from which chocolate is made, and also of the cocoa-nut. Vegetable wax is of the same nature, only more solid. It is the production of China; and is there made into yellow, white, or green candles, the colour varying according to the manner in which the wax is extracted. The catkins of birch and poplar afford a small quantity of a similar wax. M. Berthollet easily whitens it with oxygenated muriatic acid.

Fat oils exposed to the air attract its oxygen, and become acid or rancid. Water and spirit of wine, by abstracting this acid, deprive them of their strong taste, but never completely restore them to their original state. M. Berthollet has discovered that fat oils, thinly spread on the surface of water, and exposed to the air, become thick, and assume the appearance of wax. This appears to arise from the absorption of oxygen, as the oxygenated muriatic acid produces this change more suddenly.

These oils afford by distillation a small quantity of water impregnated with a peculiar acid, a light oil, a dense oil, and inflammable and fixed airs. The quantity of charcoal left behind is not abundant. By re-distilling the first products, more water, and an oil which becomes lighter each time, are obtained. Lavoisier collected the products of olive-oil burned in an apparatus properly constructed to ascertain their nature and properties. He obtained seventy-nine parts of carbon, and twenty-one of hydrogen, from one hundred of oil. From these component parts, inferences may be drawn respecting the acid, the water, the fixed air, and the inflammable
air,

air, afforded by partial decompositions or combustions of this fluid. When oils are burned in pure air, one of their component principles, hydrogen, is combined with pure air, and forms water; while charcoal, its other component part, combines with pure air also, and forms fixed air.

The dense animal oils, such as butter, tallow, fat, and the oil of the whale, exceedingly resemble vegetable fixed oils. They appear, however, to contain a proportion of azotic air and animalized matter, probably in the state of serum or jelly.

Agitation in water separates a mucilaginous matter from fat vegetable oils, which seems to be the cause of their becoming rancid. They combine with pure fixed alkalies into soap, and they also unite with magnesia and lime, which form with them soapy compounds.

IV. ESSENTIAL OILS are remarkable for a strong aromatic smell, and are sufficiently volatile to rise with the heat of boiling water. They are in general soluble in spirit of wine, and their taste is very acrid. They are much more inflammable than the fat oils.

Essential or volatile oils exist in most fragrant vegetables, and in various plants are found in different parts; thus the oil of cinnamon is found in the bark; of balm, peppermint, and wormwood, in the leaves; of the rose and lavender, in the flower; of nutmegs, anise, and fennel, in the seeds. They are obtained either by expression, as from the peel of oranges and lemons, or by distillation with water. For the latter purpose, the plant is

put into a copper alembic, with water; the water being made to boil, comes over together with the oil into the receiver, and is obtained separate by decantation. Some of the essential oils are fluid, as that of lavender; others congeal by cold, as that of anniseed; others are always concrete, as those of roses and parsley. They differ much with respect to colours: thus, oil of lavender is yellow, that of cinnamon deep yellow, that of parsley green, that of camomile blue. Some of the essential oils float in water, as most of the oils obtained from plants growing in temperate climates; others, as those of sassafras and caraway-seeds, and most of the oils from hot countries, sink in that fluid. This property is not, however, invariable with respect to climate, as the essential oils of nutmeg, pepper, and mace are lighter than water. It is remarkable, that essential oils sometimes entirely differ in their properties from the plant which affords them; thus, oil of pepper is mild, and oil of wormwood is not bitter.

The perfume, or principle of scent, in plants, to which Boerhaave gave the name of *spiritus rector*, seems in general to reside in the essential oil. It composes an extremely small part of the weight of vegetables, as may be inferred from the loss of fragrance sustained by essential oils with little or no loss of weight. It does not seem improbable, that the perfume, or principle of scent, in plants, is a gas of a peculiar nature. Its invisibility and volatility, the manner in which it is expanded and dispersed in the atmosphere, together with certain experiments made by Dr. Ingenhouz, on the noxious gas afforded

forded by flowers, render this opinion very probable.

It is easy to discover the adulteration of volatile oils, either by pouring ardent spirit on them, which will not dissolve the fat oil they may be contaminated with; or if they are dropped on paper, and held to the fire, the essential oil evaporates, leaving the fat oil behind, which makes a greasy spot. If oil of turpentine is fraudulently added to them, its smell betrays its presence when treated in this manner. By exposure to the air they become thick, and in process of time assume the character of resin. Needle-shaped crystals are deposited similar to those afforded by camphor when sublimed. Geoffroy the younger observed them in the essential oils of motherwort, marjoram, and of turpentine. The same chemist observes, that their smell is similar to that of camphor.

Essential oils combine very readily with sulphur, and form compounds called balsams of sulphur, in which the sulphur is so far changed that it cannot be recovered.

V. The proper vegetable BALSAMS are oily aromatic substances, imperfectly fluid, obtained by incisions made in certain trees. The word balsam has been used in a very extensive sense, to denote a variety of vegetable substances, which agree in consistence, though differing very widely in their nature and properties. This denomination, however, is more properly confined to such resinous matters as possess a fragrant smell, and more especially contain acid, odorant, and concrete salts, which
may

may be extracted by decoction or sublimation; such as benzoin, balsam of Tolu, and storax.

VI. CAMPHOR is a peculiar vegetable substance, of a strong smell and taste, which resembles essential oils in some of its properties, and differs from them in others. It is much more volatile than the essential oils; with the most gentle heat it sublimes and crystallizes in hexagonal laminæ attached to a middle stem. By a sudden heat it melts before it rises. Water does not dissolve it; but it is plentifully soluble in spirit of wine, æther, and concentrated acids, from the two former of which it is separated by the addition of water without alteration. Fixed and volatile oils dissolve camphor with the assistance of heat, and deposit crystals in the form of a beautiful vegetation by cooling. A peculiar acid is formed by the distillation of nitrous acid with this substance. Camphor has been obtained in small quantities from the roots of zedoary, thyme, rosemary, sage, anemony and other vegetables, by distillation. It is observable, that all these plants afford a much larger quantity of camphor, when the sap has been suffered to pass to the concrete state by several months drying. Thyme and peppermint, slowly dried, afford much camphor; and M. Achard has observed, that a smell of camphor is disengaged when volatile oil of fennel is treated with acids. M. Chaptal concludes, from these and some other facts of the same kind, that the base of camphor forms one of the constituent parts of some volatile oils, in which it exists in the liquid state,

state, and does not become concrete, but by combining with the base of vital air.

The camphor of commerce is obtained from a species of laurel which grows in China, Japan, and in the islands of Borneo, Sumatra, Ceylon, &c. The tree which produces it sometimes contains it in so large a quantity, that it need only be cleft, in order to obtain very pure tears of camphor, of considerable size. The roots of this tree afford camphor in by far the greatest abundance, but it is also procured from the branches, trunk and leaves. The method of obtaining the camphor is by distilling the different parts of the tree with water. The alembic in which the operation is performed is covered with a capital or head filled with straw. On the application of a sufficient heat, the camphor is sublimed in small greyish grains, which are afterwards united into larger masses. The camphor in this state is impure; it is purified after being brought to Europe, principally in Holland, where it undergoes sublimation in low flat-bottomed glass vessels. Chaptal says, that the Dutch mix an ounce of quick-lime with every pound of camphor previous to distillation.

VII. RESINS are dried juices of plants, of the nature of essential oils. Almost all the concrete juices distinguished by the name of resins are soluble in ardent spirit, and not in water, whereas gums are soluble in water, and not in spirit. They usually flow from wounds made in the trunks of trees purposely to obtain them. They are inflammable, and burn with much smoke. In closed vessels

sels they do not rise wholly by heat, but are decomposed. Resins differ from balsams in their smell, which is less agreeable, and especially in their containing no concrete acid salt. The common resin of the pine, the resin of the fir, pitch, tar, and turpentine, are perfect resins, and are soluble in spirit of wine. Copal, and the elastic substance called *caoutchouc*, which is the inspissated juice of an African tree, are usually but improperly reckoned among resinous substances; though neither spirit of wine nor water dissolves them. They are soluble, however, in oils, by the assistance of heat, and have been thought to be of the nature of fat oils, though they differ in many remarkable properties.

The juices called gum-resins, or the mixtures of gum and resin, are not completely soluble either in water or spirit of wine. Both these menstrua, however, by dissolving one of the component parts, suspend a portion of the other, from their intimate union.

VIII. PURE FECULA OF VEGETABLES.—If the substance of a vegetable is reduced to a pulp by pounding, this pulp by strong pressure affords a turbid white or coloured fluid, which by standing deposits a substance, more or less fibrous or pulverulent, according to the nature of the vegetable substance from which it was obtained. This is called the fecula of vegetables, and consists almost entirely of starch. Some parts of vegetables appear to be altogether composed of this matter; such as the seeds of the gramineous and leguminous plants, tuberous roots, &c. These parts in general afford

afford the finest and most abundant fecula. The stems and leaves of vegetables afford only a coarse filamentous deposition, but if this is powdered and washed, the water carries off a fine fecula, perfectly similar to that afforded by grain. All vegetables therefore, and all the parts of them, afford more or less of this matter; the only difference is, that in some parts it is naturally disengaged from other substances, in others it is in such a state, that it must be separated by a laborious process. The fecula of some vegetables is separated as an article of food: as from the root of briony, from potatoes, from the root of a very acrid plant called manioc, from the pith of a kind of palm which grows in the Moluccas, which affords the fecula called sago; and from the root of a species of orchis, which affords salep.

IX. FARINA.—Flour, or the pulverized substance of farinaceous seeds, has a strong analogy with the gummy and saccharine mucilages. Farinaceous seeds, if kept in a moderate temperature, and supplied with moisture, are, by the incipient process of vegetation, converted in a great measure into saccharine mucilages, as happens in making malt. Wheat-flour is the most perfect farina with which we are acquainted, and I shall therefore confine my description to it; though it must be confessed that this description will not apply in all respects to the more imperfect species of farina.

If a handful of wheat-flour is taken and kneaded in a vessel of water, underneath a stream from a
cock,

cock, the water carries off a fine white powder, and the kneading must be continued till the water passes off clear. The flour is then found to be separated into three substances; a greyish and elastic matter remaining in the hand, which is called the glutinous or vegeto-animal part; a white powder deposited by the water, which is the fecula or starch; and a substance held in solution by the water, which is of a saccharine mucilaginous nature.

The glutinous matter existed before in the flour in a pulverized form, and acquires its tenacity by imbibing a portion of the fluid, but is totally insoluble in it. It has scarcely any taste, is elastic, ductile, and of a whitish grey colour. When drawn out, it extends to the length of about twenty times its diameter before it breaks, and appears as if composed of fibres placed beside each other, according to the direction in which it has been drawn. If the force ceases, it recovers its original form by its elasticity. When dry it is semi-transparent, and resembles glue in its colour and appearance. If it is drawn out thin when first obtained, it may be dried by exposure to the air, and in that state has a polished surface, resembling that of animal membranes. If it is exposed to warmth and moisture while wet, it putrefies like an animal substance. If this gluten in its dried state is placed on burning coals, or held in the flame of a candle, it exhibits the characters of an animal substance; it crackles, swells and burns, exactly like a feather or piece of horn. By distillation it affords, like animal substances, alkaline water, concrete volatile

latile alkali, and an empyreumatic oil. Its coal is very difficultly incinerated, and does not afford fixed alkali.

From these facts it follows, that this substance is totally different from all the others known to exist in vegetables, and in many of its characters resembles the fibrous part of the blood. It is to this gluten that wheat-flour owes its property of forming a very adhesive paste with water. This gluten does not appear to exist in any considerable quantity in other farinaceous substances, as rye, barley, buck-wheat, rice, &c. M. Berthollet thinks that this glutinous substance contains phosphoric salt, like animal matters, and that this is the reason of the difficulty with which it is incinerated. Rouelle the younger found a glutinous substance in the fecula of plants, analogous to that of wheat.

The powder which I remarked, as being separated from the farina, and which, being only suspended and not dissolved in the water, falls to the bottom by rest, is the amylaceous fecula or starch, which indeed composes the greater part of the flour. This substance is very fine and soft to the touch; its taste is scarcely sensible. When first extracted by the process which has been described, its colour is greyish; but the starch-makers render it extremely white, by suffering it to remain in the water for a time, after it has become acid.

Starch seems nearly allied to mucilaginous matters, and is totally different from the glutinous substance last described. Its habitudes and products with the fire, or with nitrous acid, are nearly the same as those of gum and of sugar; but it differs from

from these substances in being scarcely, if at all, acted on by cold water, though with hot water it forms a gelatinous fluid. It seems to be more remote from the saline state than gum, as gum is more remote from it than sugar. Starch burns without emitting an empyreumatic smell. By distillation with a naked fire, it affords an acid water of a brown colour, and a very thick oil towards the end of the process. Its coal is easily reduced to ashes, which contain fixed alkali.

The substance which was mentioned as being dissolved in the water in which flour is washed, does not essentially differ from other saccharine mucilages. By evaporating the water in which it is contained, M. Poulletier obtained a viscous glutinous substance, of a brownish yellow colour, and slightly saccharine taste. This substance, called by its discoverer the mucofo-saccharine matter, exhibited all the phenomena of sugar in its combustion and distillation. It is this which excites the acid fermentation in the water which floats above starch; for, as Macquer well observes, the latter is not at all soluble in cold water. The mucofo-saccharine matter exists in a very small proportion in wheat-flour. M. Fourcroy, however, is of opinion, notwithstanding the small quantity of it, that it is the part principally concerned in the fermentation by which bread is leavened.

With respect to what is the nutritional part of flour, all the substances into which it is resolved, by washing it in water, seem well adapted to this purpose; but as the amylaceous matter is the most abundant, so it is probably the most important ingredient

gradient. The amylaceous matter in wheat is to the glutinous in the proportion of about three to two.

Bread is the farina of grain, made into a paste with water, and baked. Unleavened bread, or biscuit, keeps longest without spoiling, and is therefore used at sea, where baking would be extremely inconvenient. Bread used on shore is in general leavened, and for this purpose a quantity of yeast is added to it, while in the state of dough; in consequence of this, and of being kept in a warm temperature, it undergoes fermentation, attended with the extrication of air, by which the particles are separated from each other, and the mass swells and becomes more porous. This distension is still further increased by the rarefaction of the air in baking, and thus is formed a substance much more miscible with water than dough, and upon this latter property seems to depend its greater wholesomeness, as being more digestible.

9. COLOURING MATTERS OF VEGETABLES. On a knowledge of the colouring matters of vegetables, depends the art of dying, which consists in extracting from various substances colouring particles, and applying them to stuffs and other matters intended to be dyed, so that they shall adhere as firmly and durably as possible. Dyers enumerate five colours, which they call primary, from the mixture of which other colours are produced: these are blue, red, yellow, nut-colour, and black. Good dyes are those which can resist the action of water, air, and of certain saline and saponaceous liquors,

which are used as the proofs of the durability of colours. False dyes are those which cannot resist these proofs.

A great number of vegetable colouring matters, which are of an extractive or saponaceous nature, are readily dissolved in water. The colouring principle of many other substances resides in a purely resinous matter, insoluble in water, and in some instances attached to matters insoluble, even in spirit of wine; but they are all acted on by alkalies, which convert them into a kind of soaps, miscible with water. The principal colours of this nature are the annotto, a kind of fecula, obtained by maceration of the seeds of the urucu putrefied in water, and which dyes an orange yellow colour; the flower of carthamus or bastard saffron, which affords a very fine red; archil, which is a paste prepared with mosses, macerated in urine with lime, and which dyes red. The colour of indigo also resides in a resinous matter.

Certain colouring substances are soluble in oils. Alkanet, or the red root of a kind of burglofs, is of this kind, but cannot be used in dying.

We may easily conceive that a coloured decoction may stain any stuff which is dipped into it, and that this colouring matter may be again abstracted by the application of the same menstruum as it was originally suspended in. But the action of those dyes, which, although once dissolved and suspended in water, cannot again, after they are applied to stuffs, be washed out, is not so easily understood. These latter, or durable dyes, alone deserve attention. Dyes of different colours require different treatment.

treatment. Stuffs to be dyed of a red or yellow colour must be boiled in water, with alum or fixed alkali, before they are dipped into the dying decoctions: the red colouring materials are kermes, cochineal, gum-lac, and madder; the yellow materials are luteola or dyers weed, and other yellow flowers. The stuffs for blue dyes require no previous preparation. These blue dyes are made of indigo, or the blue fecula obtained from woad, dissolved in a lixivium of fixed alkali, or in urine, with or without the addition of some green vitriol. The stuffs intended to receive a root colour, require no previous preparation, but to be soaked in warm water. These dyes are chiefly decoctions of walnut-shells, walnut-roots, alder-bark, sumach, and saunders. These root colours, which are all yellow, serve to form a very good ground, on which other more brilliant colours may be applied, and to them no saline or other matter is added. The black dyes, which are inks or decoctions of galls, mixed with green vitriol, require no previous preparation of the stuff.

It is observable that wool takes the dye better than silk, silk than cotton, and cotton than flax. Writers on the art of dying hold different opinions respecting the manner in which colouring particles apply themselves to the substances exposed to their contact. Many have supposed that this application takes place only in proportion to the number and magnitude of the pores in the various substances. Macquer, who has paid great attention to this subject, supposes that the greater or less facility with which the colour is applied, depends on the re-

spective nature of the colouring parts, and the substances proposed to be dyed : and that dying is truly an external tinge or painting, which succeeds and lasts by virtue of an affinity and intimate union between the colour and the dyed substance. This serves to explain the use of the matters, which it is on many occasions necessary that the stuffs should imbibe, previous to immersing them in the dying substance. The same thing may be illustrated by considering the process employed in the preparation of certain colours called lakes. Vegetable colouring matters are dissolved, and then precipitated by the addition of some other substance. Thus, for example, if madder is boiled in water, together with an alkali, and alum is then added, the earth of the alum will be precipitated, together with the colouring matter, with which it will form an insoluble pigment. A double decomposition here takes place, the vitriolic acid quits the earth of alum to unite with the fixed alkali, and the vegetable matter unites itself with the earth.

CHAP. VI.

FERMENTATION.

Three Kinds of Fermentation.—The vinous or spirituous.—Spirit of Wine or Alcohol.—Ether.—Acetous Fermentation.—Putrid Fermentation.—Observations on Putrefaction in general.

HAVING considered the structure and composition of vegetable substances, it becomes necessary to direct our attention to certain spontaneous changes which they undergo, when deprived of the vital principle. These changes are called fermentations, which are three in number, and are termed, from their products, the vinous or spirituous, the acetous, and the putrid. The circumstances universally necessary to fermentation are moisture, a certain degree of heat, and the contact of air. The three kinds of fermentation are sometimes considered as different stages of one process; this, however, is an improper view of the subject, as each kind of fermentation is a peculiar process, and totally different from every other. Some bodies become acid without having undergone the spirituous fermentation, and others putrify without

F 3

shewing

shewing any disposition to assume either that or the acetous state.

The conditions necessary for the production of the *VINOUS* or *spirituous* fermentation are—1. A degree of fluidity slightly viscid.—2. The presence of saccharine mucilage. It is found that the fermentable juices of fruits, boiled till they become thick, are indisposed to ferment, and this not only in their inspissated state, but when diluted again with water: for this reason it is, that in the making of sugar nothing is of more importance than the juice of the cane being submitted to boiling immediately on being expressed. Preserves, and other mixtures prone to fermentation, are prevented from that process by the same method.—3. A proper temperature, which varies from forty-eight to eighty of Fahrenheit's thermometer. If below this, the fermentation is languid; if above it, it is impetuous, and is apt to rush into the acetous state even before the vinous.—4. The addition of a quantity of the substance called yeast, which is itself the product of the vinous fermentation, is of great assistance in exciting it. By what power yeast acts in producing the vinous fermentation, has been much disputed. Mr. Henry thinks that yeast is no other than fixed air already formed, but enveloped or entangled in the mucilaginous matter of the liquor from which it was obtained; and the same ingenious experimentalist was able to bring on the vinous fermentation, by adding to common wort a quantity of fixed air in the elastic form. To account for this, it is not difficult to

suppose that fixed air has an attraction for its own constituent principles, when placed in favourable circumstances to act upon them; and that it will thus occasion the separation of fixed air from the fermentable liquor, which is so remarkable during fermentation.

The phenomena which present themselves in a liquor during the spirituous fermentation are—First, A muddiness, from the separation of an aerial matter, which rises in bubbles to the top in such quantity, and in such quick succession, as to produce a hissing noise, and form a froth. These minute globules of air occasion the motion of the particles of the fluid among one another; and this motion is perceptible, even before the air is visibly separated. The globules of air attach themselves to the particles of the mixture, and buoy them up; at length the globule is detached, and the atom sinks by its own weight. The nature of the air which is disengaged was not understood till the modern experiments on aeriform fluids afforded so much assistance to chemical science. It is now ascertained to be the carbonic acid gas, or fixed air, which, being heavier than atmospheric air, forms a stratum in the upper part of the vessel in which the fluid is fermenting, where it may be perceived from its greater density. This air, contained in the fermenting vats of brew-houses, frequently produces the most fatal effects on the workmen; and a candle dipped into it is as certainly extinguished as if plunged into water. During the time that the fermentation is going on,

the bulk of the liquid is augmented. Another phenomenon is the production of a gentle heat, equal to about seventy-two degrees of Fahrenheit's thermometer. After some days, the number of which varies according to the dilution of the substance and the degree of heat, the motion in the fluid diminishes, the warmth abates, and the emission of air is lessened; the liquor becomes clear, and the scum, which consists of the more solid particles and air, becomes heavier in proportion as the air escapes, and at last sinks. The liquor has now undergone a great change; it has acquired a pungent and pleasant taste and smell, and an inebriating quality, and has lost its sweetness. If the liquor is now distilled, instead of an insipid matter, we obtain an ardent spirit, and a four, gross fluid remains behind*.

By

* The phenomena of fermentation have long been known; but it remained for Lavoisier to ascertain with accuracy what happens in that process. I shall therefore extract his experiments and conclusions, as stated by himself, in his Elements of Chemistry.

TABLE I. *Materials of Fermentation.*

		<i>lbs. oz. gros grs.</i>			
Water	-	-	400	0	0 0
Sugar	-	-	100	0	0 0
Yeast in paste, 10 <i>lbs.</i> composed of	Water	-	7	3	6 44
	Dry yeast	-	2	12	1 28
Total		-	510	0	0 0

TABLE

By the experiments of Lavoisier, it appears that ardent spirit (alcohol) or the product of the vinous

TABLE II. *Constituent Elements of the Materials of Fermentation.*

		libs.	oz.	gros	grs.
407 lbs. 3 oz. 6 gros 44 grs. of water, composed of	{ Hydrogen	61	1	2	71.40
	{ Oxygen	346	2	3	44.60
100 lbs. sugar, composed of	{ Hydrogen	8	0	0	0
	{ Oxygen	64	0	0	0
	{ Charcoal	28	0	0	0
2 lbs. 12 oz. 1 gros 28 grs. of dry yeast, composed of	{ Hydrogen	0	4	5	9.30
	{ Oxygen	1	10	2	28.76
	{ Charcoal	0	12	4	59
	{ Azote	0	0	5	2.94
Total weight -		510	0	0	0

TABLE III. *Recapitulation of these Elements.*

		libs.	oz.	gros	grs.		libs.	oz.	gros	grs.
Oxygen.	{ of the water	340	0	0	0	}	411	12	6	1.36
	{ of the water									
	{ in the yeast	6	2	3	44.60					
	{ of the sugar	64	0	0	0					
	{ of the dry yeast	1	10	2	28.76					
Hydrogen.	{ of the water	60	0	0	0	}	69	6	0	8.70
	{ of the water									
	{ in the yeast	1	1	2	71.40					
	{ of the sugar	8	0	0	0					
	{ of the dry yeast	0	4	5	9.30					
Char-coal.	{ of the sugar	28	0	0	0	}	28	12	4	59.00
	{ of the yeast	0	12	4	59.00					
Azote of the yeast		-	-	-	-		0	0	5	2.94
In all		510	0	0	0					

‘ Having

nous fermentation, consists of the same principles as sugar, except that they are combined in different proportions. Ardent spirit contains more hydrogen, and less carbon and oxygen; which latter principles compose the carbonic acid gas which escapes during the spirituous fermentation. M. Lavoisier found that when ardent spirit is burned in a chimney adapted to receive the vapours,

* Having thus accurately determined the nature and quantity of the constituent elements of the materials submitted to fermentation, we have (adds M. L.) next to examine the products resulting from that process. For this purpose, I placed the above 510 *lbs.* of fermentable liquor in a proper apparatus, by means of which I could accurately determine the quantity and quality of gas disengaged during the fermentation, and could even weigh every one of the products separately, at any period of the process I judged proper. An hour or two after the substances are mixed together, especially if they are kept in a temperature of from 15° (63.75°) to 18° (72.5°) of the thermometer, the first marks of fermentation commence; the liquor turns thick and frothy, little globules of air are disengaged, which rise and burst at the surface; the quantity of these globules quickly increases, and there is a rapid and abundant production of very pure carbonic acid, accompanied with a scum, which is the yeast separating from the mixture. After some days, less or more, according to the degree of heat, the intestine motion and disengagement of gas diminish; but these do not cease entirely, nor is the fermentation completed for a considerable time. During the process, 35 *lbs.*, 5 *oz.*, 4 *grs.* 19 *grs.* of dry carbonic acid are disengaged, which carry along with them 13 *lbs.* 14 *oz.* 5 *grs.* of water. There remains in the vessel 460 *lbs.* 11 *oz.* 6 *grs.* 53 *grs.* of vinous liquor, slightly acidulous. This is at first muddy, but clears of itself, and deposits a portion of yeast. When we separately analyse all these substances, which is effected by very troublesome

pours, a larger quantity of water is formed than the whole of the spirit employed amounts to; whence it follows, that ardent spirit contains a large proportion of hydrogen, which forms water, by combining with the vital air of the atmosphere during

some processes, we have the results as given in the following tables.

TABLE IV. *Products of Fermentation.*

		<i>libs. oz. gros. grs.</i>			
35 <i>libs.</i> 5 <i>oz.</i> 4 <i>gros.</i> 19 <i>grs.</i> of carbonic acid, composed of	Oxygen	-	-	25	7 1 34
	Charcoal	-	-	9	14 2 57
408 <i>libs.</i> 15 <i>oz.</i> 5 <i>gros.</i> 14 <i>grs.</i> of water, composed of	Oxygen	-	-	347	10 0 59
	Hydrogen	-	-	61	5 4 27
57 <i>lbs.</i> 11 <i>oz.</i> 1 <i>gros.</i> 58 <i>grs.</i> of dry alcohol, composed of	Oxygen, combined with hydrogen	-	-	31	6 1 64
	Hydrogen, combined with oxygen	-	-	5	8 5 3
	Hydrogen, combined with charcoal	-	-	4	0 5 0
	Charcoal, combined with hydrogen	-	-	16	11 5 63
2 <i>libs.</i> 8 <i>oz.</i> of dry acetous acid, composed of	Hydrogen	-	-	0	2 4 0
	Oxygen	-	-	1	11 4 0
	Charcoal	-	-	0	10 0 0
4 <i>libs.</i> 1 <i>oz.</i> 4 <i>gros.</i> 3 <i>grs.</i> of residuum of sugar, composed of	Hydrogen	-	-	0	5 1 67
	Oxygen	-	-	2	9 7 27
	Charcoal	-	-	1	2 2 53
1 <i>lib.</i> 6 <i>oz.</i> 0 <i>gros.</i> 5 <i>grs.</i> of dry yeast, composed of	Hydrogen	-	-	0	2 2 41
	Oxygen	-	-	0	13 1 14
	Charcoal	-	-	0	6 2 30
	Azote	-	-	0	0 2 37
510 <i>libs.</i>		Total 510 0 0 0			

TABLE

during combustion. That it also contains a proportion of carbon, has been proved by M. Berthollet,

TABLE V. *Recapitulation of the Products.*

			libs.	oz.	grs	grs.
409 <i>libs.</i> 10 <i>oz.</i> 0 <i>grs.</i> 54 <i>grs.</i> of oxygen, contained in the	{	Water - -	347	10	0	59
		Carbonic acid -	25	7	1	34
		Alkohol - -	31	6	1	64
		Acetous acid -	1	11	4	0
		Residuum of sugar	2	9	7	27
		Yeast - -	0	13	1	14
28 <i>libs.</i> 12 <i>oz.</i> 5 <i>grs.</i> 59 <i>grs.</i> of charcoal contained in the	{	Carbonic acid -	9	14	2	57
		Alkohol - -	16	11	5	63
		Acetous acid -	0	10	0	0
		Residuum of sugar	1	2	2	53
		Yeast - -	0	6	2	30
71 <i>libs.</i> 8 <i>oz.</i> 6 <i>grs.</i> 66 <i>grs.</i> of hydrogen, contained in the -	{	Water - - -	61	5	4	27
		Water of the alkohol	5	8	5	3
		Combined with the charcoal of the alko.	4	0	5	0
		Acetous acid -	0	2	4	0
		Residuum of sugar	0	5	1	67
		Yeast - -	0	2	2	41
2 <i>grs</i> 37 <i>grs.</i> of azote in the yeast -			0	0	2	37
510 <i>libs.</i>			Total 510 0 0 0			

‘ In these results, I have been exact, even to grains; not that it is possible, in experiments of this nature, to carry our accuracy so far; but as the experiments were made only with a few pounds of sugar, and as, for the sake of comparison, I reduced the results of the actual experiments to the quintal or imaginary hundred pounds; I thought it necessary to leave the fractional parts precisely as produced by calculation,

‘ When we consider the results presented by these tables with attention, it is easy to discover exactly what occurs during fermentation. In the first place, out of the 100 *libs.* of sugar employed, 4 *libs.* 1 *oz.* 4 *grs.* 3 *grs.* remain, without having

thollet, who found that when a mixture of ardent spirit and water is burned, the residual fluid precipitates lime-water, which must proceed from its containing some carbonic acid. Spirit of wine assumes the form of an elastic fluid at the temperature of 185 degrees.

having suffered decomposition; so that, in reality, we have only operated upon 95 *libs.* 14 *oz.* 3 *grs.* 69 *grs.* of sugar; that is to say, upon 61 *libs.* 6 *oz.* 45 *grs.* of oxygen, 7 *libs.* 10 *oz.* 6 *grs.* 6 *grs.* of hydrogen, and 26 *libs.* 13 *oz.* 5 *grs.* 19 *grs.* of charcoal. By comparing these quantities, we find that they are fully sufficient for forming the whole of the alcohol, carbonic acid, and acetous acid produced by the fermentation. It is not, therefore, necessary to suppose that any water has been decomposed during the experiment, unless it is pretended that the oxygen and hydrogen exist in the sugar in that state. On the contrary, I have already made it evident that hydrogen, oxygen, and charcoal, the three constituent elements of vegetables, remain in a state of equilibrium or mutual union with each other, which subsists so long as this union remains undisturbed by increased temperature, or by some new compound attraction; and that then only these elements combine, two and two together, to form water and carbonic acid.

‘ The effects of the vinous fermentation upon sugar are thus reduced to the mere separation of its elements into two portions; one part is oxygenated at the expence of the other, so as to form carbonic acid, whilst the other part, being disoxygenated in favour of the former, is converted into the combustible substance alcohol; therefore, if it was possible to re-unite alcohol and carbonic acid together, we ought to form sugar. It is evident that the charcoal and hydrogen in the alcohol do not exist in the state of oil, they are combined with a portion of oxygen, which renders them miscible with water; wherefore these three substances, oxygen, hydrogen, and charcoal, exist here likewise, in a species of equilibrium or reciprocal combination; and in fact, when they are made to pass through a red hot tube of glass or porcelain, this union or equilibrium is destroyed, the elements become combined two and two, and water and carbonic acid are formed.

Spirit of wine and the acids act with considerable violence on each other. When strong vitriolic acid is poured on an equal quantity of rectified spirit of wine, a strong heat, with a remarkable hissing noise, are excited; the two substances become coloured, and emit a sweet smell, resembling that of lemons, or the apple called golden rennet. If the mixture is made in a retort, and then submitted to distillation in the well-regulated heat of a sand bath, a large receiver, kept cool by the application of moistened cloths, being adapted, the volatile products may be condensed. These are: 1. Spirit of wine of a sweet smell. 2. A fluid called *ether*, extremely volatile, and also of a pleasant odour; this comes over as soon as the fluid in the retort begins to boil, and the upper part of the receiver is at the same time covered with large distinct streams of the fluid, which run down its sides. 3. A light yellow oil, called sweet oil of wine; and 4, a sulphureous spirit passes over, the white colour and smell of which indicate the proper time for changing the receiver, in order to have the ether separate; and this is succeeded by black and foul vitriolic acid.

Ether is a fluid of a peculiar nature. It is the lightest and most volatile of all unelastic fluids, and its tendency to assume the elastic form is so strong, that it is quickly dissipated in the ordinary heat of the atmosphere, unless confined. It is highly inflammable, so that it is dangerous to bring a candle near any considerable quantity of it, the vapour taking fire, and communicating the inflammation to the whole volume. The acids with which spirit of
wine

wine is distilled, in order to obtain ether, seem to effect this principally by robbing the spirit of part of its carbon, which latter substance occasions the dark colour in the mixture, by decomposing the acid. A small part of the acid adheres to the ether in its ascent, and this constitutes the differences which exist among the ethers, according to the acid by which they were produced.

THE ACETOUS FERMENTATION is still more simple than the spirituous, and consists merely in the absorption of the vital or oxygenous part of the atmosphere, by which vinous fluids are converted into vinegar; whence it appears that it is the proportion of oxygen alone which constitutes the vast difference which exists between ardent spirit and vinegar. That wine is converted into vinegar, by the addition of oxygen, is proved, as well from the general analogy of the formation of other acids, as by the following direct experiments. In the first place, we cannot change wine into vinegar, without exposing the former to the contact of air containing oxygen, or employing some other mode of oxygenation; secondly, this process is accompanied by a diminution of the volume of the air in which it is carried on, from the absorption of oxygen; and thirdly, wine, by being converted into vinegar, is increased in weight.

THE PUTRID FERMENTATION is the destruction of the equilibrium which holds the constituent principles of bodies in a state of combination. Thus a vegetable substance, which when entire consists of a triple combination of hydrogen, oxygen, and carbon, is resolved by putrefaction into hydrogen
gas,

gas, and carbonic acid gas, which consists of oxygen and carbon. As there is not enough of oxygen to convert all the carbon into carbonic acid gas, a quantity of the charcoal remains behind, mixed with the earthy and saline matter contained in the vegetable. Thus putrefaction in a vegetable substance, is nothing more than a complete analysis of it, in which the constituent elements are disengaged in the form of gas, except the earth, and a quantity of charcoal which remains in the state of mould.

Such is the result of putrefaction when the substances submitted to it contain only oxygen, hydrogen, charcoal, and a little earth. But this case is rare; and these substances putrefy imperfectly, and with difficulty. It is otherwise with substances containing azote, which indeed exists in all animal matters, and in a considerable number of vegetables. The putrid fermentation of animal substances is commonly called putrefaction, and this is well known to take place in them, after they are deprived of life. The circumstances which favour putrefaction are the same as those which promote the spirituous and acetous fermentations, viz. humidity, the admission of air, and a due degree of heat. Heat to a certain degree promotes putrefaction, yet 20° above that of the human blood seems to prevent it. A small piece of fish which was luminous, and consequently putrid, was put into a thin glass ball, and water of the heat of 118° extinguished its light, and consequently stopped its tendency to putrefaction, in less than half a minute; on taking it out of the water, it began to recover its light in
about

in about ten seconds, but was never so bright as before *.

Azote, which abounds so much in animal substances, not only occasions a more rapid putrefaction, but renders its products considerably different from those afforded by the decay of such vegetables as do not contain azote. In the putrefaction of animal matters, the hydrogen, instead of escaping in a separate state, combines with the azote, and forms volatile alkali. The hydrogen gas also dissolves a part of the carbon, the sulphur, and the phosphorus, all which substances enter into the composition of animal matter; with these, it forms compound aeriform fluids, which have obtained the following names, carbonated hydrogen gas, sulphurated hydrogen gas, and phosphorated hydrogen gas. The two latter of these gasses have a peculiar, disagreeable odour, and, together with the volatile alkali, occasion the penetrating and offensive exhalations which proceed from putrid matters. Sometimes volatile alkali predominates, which affects the eyes; sometimes, as in feculent matters, the sulphurated gas is most prevalent; and sometimes, as in putrid herrings, the phosphorated hydrogen gas is most abundant. Carbonic acid gas is also disengaged. It appears highly probable, that water, which is so necessary to putrefaction, is decomposed during that process, and that its component principles, oxygen and hydrogen, contribute to the great quantity of gasses which are produced. Oxygen seems also to be absorbed

* Priestley's Hist. of Optics, p. 579.

82 *Muscular Matter changed into Oil.* [Book VIII.]

from the atmosphere; since putrefaction is expedited by vital air.

M. Fourcroy and M. Thouret have observed some peculiar phenomena in dead bodies, buried at a certain depth, and preserved to a certain degree from contact of air; having found the muscular flesh converted into true animal fat. This must have arisen from the disengagement of the azote by some unknown cause, leaving only the hydrogen and charcoal remaining, which are the elements of fat or oil. This observation, M. Lavoisier remarks, may at some future period lead to discoveries of great importance to society, by enabling the chemist to convert into oil substances which consist of nearly the same principles, but which are at present of no value.

The decomposition of vegetable matters by fire, was noticed, in treating of inflammable substances, in the chapter on carbon or the carbonaceous principle; and the mode of extracting from the ashes of certain plants that useful substance the fixed alkali, has been also described.

There is perhaps no process of nature better understood than that of fermentation, and yet there is not any more calculated to excite our astonishment; there is not any instance within my recollection so striking, of the surprizing change which combination produces in bodies; and it is the more wonderful, when we consider, that different proportions of the same ingredients produce fluids essentially distinct in all their leading characters. He that "made a weight for the winds, and weigheth the waters by measure;" how excellently has he ordered all things for the benefit of his creatures!

tures! "The undevout astronomer is mad," is the strong expression of a sublime writer; yet, if the wisdom and providence of God is evident in those immense bodies, of the structure of which we are in a great measure ignorant, surely it is much more so in these minute operations, which are the immediate objects of our senses, where every thing is plainly the effect of intelligence and design; and, however ignorant and superficial observers may wander from the path of truth, the naturalist at least can never be an atheist.

BOOK IX.

OF ANIMALS.

CHAP. I.

OF ANIMAL MATTER IN GENERAL.

General Remarks on organized Bodies.—Products from the Distillation of Animal Matter.—Elementary Principles which enter into the Composition of Animal Matter.—Animal Acids.—Different Forms of Animal Matter.—Jelly.—Glue.—Lymph.—Further Products.—Fat.—Fibrous Parts.

IN treating of organized bodies, as introductory to an account of the vegetable system, some observations were made, which are also in a great measure applicable to animal nature. The elementary principles, however, which enter into the composition of animal bodies are more numerous than those which are found in vegetable matter; and at the same time the structure of animals is much more complex than that of plants. In both, the growth and increase is provided for by a curious kind of chemical apparatus, adapted for effecting those wonderful changes, dissolutions, and combinations of matter, which are essential to their respective natures. All, however, that we have been able to discover in vegetables, is some traces of a vascular system; whereas, in animal nature, there is not only a most elaborate system of vessels, but

means

means provided for the augmentation of the temperature, and for the fulfilling of those functions which belong to a creature, endued with a power of voluntary motion, and of thought.

To describe with accuracy the specific characteristics of different animals, to enter into the detail of what is called comparative anatomy, would employ an immense and elaborate treatise; and indeed to acquire the necessary knowledge for such an undertaking would occupy a long life. As the object, however, of the present work is to give a general view of nature, rather than to enter into that minuteness of disquisition which is chiefly necessary for technical purposes, or for those inquirers whose leisure and patience far exceed those of the majority of mankind, it will be necessary to confine the present subject within reasonable limits. And since it would be impossible in such a work to treat of the specific organization of every animal, I have made choice of that one, whose parts and functions are found to be the most perfect; and as it is easier to look down from an eminence than to ascend the heights of creation, from what will be stated in the succeeding pages on the economy of the human body, it will not be a matter of great difficulty to comprehend that of other animals*. The plan which will be pursued in this part of the work will not be materially different from that which has been adopted in the preceding. After a few obser-

* The most striking and characteristic differences in the fabric of different animals are however noticed; but to describe minutely the natural economy of every distinct race of animals, would require an immense treatise, and indeed has never yet been done,

vations on the component principles of animal matter, I shall proceed to consider the structure of those organs which constitute the animal machine; and lastly, the functions to which those organs are subservient.

When animal matter is distilled with a strong heat, we obtain a watery fluid, holding in solution some sal ammoniac, supersaturated with volatile alkali; a light oil, and a ponderous dark oil, mixed with concrete volatile alkali; a spongy coal remains in the retort, of difficult incineration, and which contains sea-salt, mild fossile alkali, iron, and calcareous earth, combined with phosphoric acid.

Such are the products afforded by the distillation of all animal matters, except that the proportions vary, according to the degree of solidity in the part submitted to distillation. The most characteristic mark of animal matter, is its containing azote, which considerably alters its products, both by putrefaction and distillation, and which in both these processes combining with hydrogen produces volatile alkali. As vegetables and animals, however, pass by insensible degrees into each other, so there are some vegetables which afford volatile alkali, and which consequently contain azote; though in far less quantity than any animal matter.

The elementary matters which enter into the composition of the soft parts of animals, are carbon, hydrogen, azote and oxygen; the bones are composed of calcareous earth and phosphoric acid: a very small quantity also of iron, and of some neutral salts, particularly such as are composed of the mineral and volatile alkalies, and lime, combined

bined with the muriatic, phosphoric and cretaceous acids, are discovered by careful analysis. By the application of heat, the elementary matters above mentioned assume new arrangements and combinations; hydrogen and oxygen uniting, form water; hydrogen and carbon, oil; hydrogen and azote, volatile alkali; oxygen and carbon, cretaceous or carbonaceous acid; some of the gasses also escape in a separate state, and part of the carbon remains behind with the earthy matter. Lavoisier, after having treated of the decomposition of vegetable matter, observes :

‘ Animal substances, being composed nearly of the same elements with cruciferous plants, give the same products in distillation, with this difference, that, as they contain a greater quantity of hydrogen and azote, they produce more oil and more ammoniac. I shall only produce one fact, as a proof of the exactness with which this theory explains all the phenomena which occur during the distillation of animal substances—which is the rectification and total decomposition of volatile animal oil, commonly known by the name of Dippel’s oil. When these oils are procured by a first distillation in a naked fire, they are brown, from containing a little charcoal almost in a free state; but they become quite colourless by rectification. Even in this state the charcoal in their composition has so slight a connection with the other elements, as to separate by mere exposure to the air. If we put a quantity of this animal oil, well rectified, and consequently clear, limpid, and transparent, into a bell-glass filled with oxygen gas over mercury, in a short time the

gas is much diminished, being absorbed by the oil; the oxygen, combining with the hydrogen of the oil, forms water, which sinks to the bottom; at the same time the charcoal which was combined with the hydrogen being set free, manifests itself by rendering the oil black. Hence the only way of preserving these oils colourless and transparent, is by keeping them in bottles perfectly full, and accurately corked, to hinder the contact of air, which always discolours them.

‘Successive rectifications of this oil furnish another phenomenon confirming our theory. In each distillation a small quantity of charcoal remains in the retort, and a little water is formed by the union of the oxygen contained in the air of the distilling vessels with the hydrogen of the oil. As this takes place in each successive distillation, if we make use of large vessels, and a considerable degree of heat, we at last decompose the whole of the oil, and change it entirely into water and charcoal. When we use small vessels, and especially when we employ a slow fire, or degree of heat little above that of boiling water, the total decomposition of these oils, by repeated distillation, is greatly more tedious, and more difficultly accomplished.’

Animal matters are compound salifiable bases brought to the state of oxyds by combination with oxygen, and which by the further addition of that principle are capable of becoming acids. Several animal acids have been discovered, some of which approach very near to the vegetable acids. Their bases have not been ascertained with accuracy, but are supposed to be different combinations of carbon, hydrogen,

hydrogen, and azote. The animal acids at present known, are the following :

Lactic acid, obtained from milk.

Saccho-lactic, from sugar of milk.

Formic, from ants.

Bombic, from silk-worms,

Sebacic, from suet.

Lithic, from urinary calculus.

Prussic, from blood, or other animal matter, by means of fixed alkali ignited with these matters.

Having mentioned the principles afforded by the complete decomposition of animal matter, it will be proper to notice certain matters into which the soft parts of animals may be resolved by the action of menstua. If a part of an animal is boiled in water, it is gradually dissolved, and a matter is extracted, which forms a solid but tremulous mass when cold, and which is called jelly. This is found most plentifully in the white parts of animals, but may be obtained in a smaller or greater proportion from all. It is nearly inodorous and insipid, and is soluble both in cold and hot water, but more easily in the latter. When its watery parts are more fully evaporated, it forms glue. The jelly of animals is very analogous to the gum of vegetables, except that the latter does not contain azote, and of course is less prone to the putrefactive fermentation, and is incapable of affording volatile alkali. The glue obtained by boiling animal matters, differs in some measure according to the firmness or laxity of the substance from which it is obtained; thus the skins, tendons, cartilages, and ligaments afford

the firmest glue. The skins of eels are the base of gold size; and from old white leather gloves and parchment is made a kind of glue used by painters. Glues differ from each other in their consistence, taste, smell, and solubility: there are some which readily become soft in cold water; others are not dissolved but in boiling water; but the preparation of the latter is not generally known. The best glue is transparent, of a yellow brownish colour, without smell and taste, and entirely soluble in water, with which it forms a viscid uniform fluid. Animal jelly differs from glue, only in possessing a less degree of consistence and viscosity. The first is more especially obtained from the soft and white parts of animals, and is far more abundant in those which are young. Glue is obtained in greatest perfection from the toughest parts of older animals. Jelly and glue are insoluble in spirit of wine.

Lymph or serum constitutes the greater part of the fluids of animals, and will be afterwards treated of as a constituent part of the blood.

Spirit of wine, when applied to animal matters, dissolves an extractive substance, which is deposited on the evaporation of the fluid; this matter is also soluble in water. It swells and liquefies by heat, and emits a smell somewhat resembling that of burned sugar; it is chiefly this substance which covers the surface of roasted meat, in the form of a brown crust.

The fat of animals approaches very nearly to the nature of the fat oils of vegetables. The globules which rise to the surface of water in which meat is boiled,

boiled, consist of the fat. The fat of animals, as well as the fat oils of vegetables, affords a peculiar acid, which is called the sebatic acid, or acid of suet.

After all these matters are extracted, there remains nothing but a white fibrous matter, insipid, and insoluble in water. This matter has all the characters of the fibrous part of the blood, which I shall treat of in the following chapter.

CHAP. II.

OF THE BLOOD.

Sanguineous and exsanguious Animals.—Warm and cold blooded Animals.—Serum and Crassamentum.—Polypuses.—Analysis of Blood.—Lymph.—Iron in the Blood.—Cause of the Red Colour.—Red Globules.—Hewson's Experiments.

THIS fluid, which is so essential to life, varies considerably in different species of animals. In man, and other large animals, it is of a red colour, but in some smaller animals the circulating fluid is nearly colourless, and therefore such animals are called exsanguious; though with little propriety, as their circulating fluid appears to answer all the purposes of blood, and there seems no reason to affirm that nothing can be blood, which is not of a red colour. The most remarkable difference in the blood of animals, is with respect to the temperature. The blood of man, quadrupeds, and birds, is hotter than the medium they inhabit; they are therefore called animals with warm blood. In fishes and reptiles it is nearly of the temperature of the medium they inhabit; and these are therefore called animals with cold blood. The temperature of the blood, as well as the change of colour to a brighter red, which the blood undergoes in passing through

through the lungs, will be treated of in a future chapter on respiration.

When blood is first drawn from a vein, it appears to be an homogeneous red fluid: it then consolidates into one uniform mass; in a little time a yellowish watery liquor begins to separate from it, which is more or less in quantity, according to the state of the blood; the red mass, in the mean time, contracts greatly in its dimensions, expelling the watery liquor from its pores, and consequently increasing in firmness and density. This separation happens in the body after death, and produces those concretions in the heart, and large vessels, those adhesive masses called polypuses, which were formerly supposed to have existed during life, and sometimes to have been the immediate occasion of death. By agitation, blood continues fluid; but a consistent fibrous matter adheres to the stick or instrument made use of to stir it, which by repeated ablution in water becomes white, and appears to be very similar to the fibres of animals obtained by washing away the other adhering matters. Received from the vein in warm water, blood deposits a quantity of transparent filamentous matter, the red portion continuing dissolved in the water. On evaporating the fluid, a red substance in the form of powder, or easily reducible to it, is left. Blood inspissated to dryness leaves a dark coloured mass, amounting at a medium to about one fourth part of its weight, of a bitter saline taste, easily inflammable, and burning with a blueish flame. The exsiccated blood is not soluble in acid or alkaline liquors, but gives some tinge to water and to spirits of wine; and

and is more powerfully acted on by dulcified spirit of nitre. Recent blood is coagulated by the mineral acids, and by most of the combinations of them with earthy and metallic bodies. With vegetable acids, and with solutions of neutral salts, it mingles equably without coagulation. Alkalies, both fixed and volatile, render it more fluid, and preserve it from coagulating. Blood by distillation affords the same results as other animal matters. Six pounds of human blood distilled to dryness, with a gentle heat, were reduced to a pound and an half; after which the mass was urged with a graduated fire, till the retort at last became red hot. The produce was seventeen ounces of liquor, twelve of which were a red and very empyreumatic volatile and alkaline fluid, and the other five were oil. What remained in the retort was a light coal, weighing four ounces and a half.

It has been already mentioned that blood spontaneously separates into two parts, a coherent mass called the *crassamentum*, and an aqueous liquor called the *serum*, with which the *crassamentum* is surrounded.

Lymph or serum, which is also called the albuminous matter, from its coagulating into a white mass by the application of a heat equal to 156 degrees of Fahrenheit's thermometer, is very analogous to the white of egg. Serum is also coagulated by acids and by ardent spirit; alkalies render it more fluid. It converts syrup of violets to a green. Its colour is yellowish, inclining to green; its taste is saline, and it feels between the fingers in some degree unctuous and adhesive. By distillation

it affords the same principles as other animal matters.

Serum, exposed to a warm temperature in the open air, passes quickly to putrefaction. It unites with water in all proportions, but they are kept separate by their different densities, unless agitated together. Serum poured into boiling water for the most part coagulates instantly. The coagulation formed in serum by the addition of an acid, dissolves very quickly in volatile alkali, which is the true solvent of the albuminous part; but it is not at all soluble in pure water. The coagulation formed by spirit of wine, on the contrary, is soluble in water, as M. Bucquet has discovered. This liquid, M. Fourcroy concludes, is an animal mucilage, composed of water, acidifiable oily bases, marine salt, chalk of soda, and calcareous phosphat; this last appears to produce the rose-coloured precipitate, obtained by pouring the nitrous solution of mercury into serum. Though the liquid is scarcely coloured, the addition of nitrous acid, and more especially of mercurial nitre, produces a rose or light flesh-colour, which M. Fourcroy has often observed in many other animal liquors.

The crassamentum, when well washed in water, is separated into two very distinct substances, one of which is dissolved, and tinges the water of a red colour, while the other remains behind in the state of a white fibrous matter, the same as that which adheres to the stirrer with which recent blood has been agitated, in order to prevent its coagulation. The water in which the red part is dissolved, when heated with different menstrua, exhibits all the characters

acters of serum; but it contains a much greater quantity of iron, which may be obtained by the incineration of the coal, and subsequent washing to separate the saline matters. The residue of this washing is a yellow calx of iron, of a beautiful colour, and usually attracted by the magnet. The red colour of the blood is therefore with some appearance of reason attributed to this metal. Iron has been obtained from the blood in considerable quantity by Menghini, Rouelle, and Bucquet.

The same chemists found that iron was capable of passing into the blood from the intestines, since patients who were under a course of martial medicines are known to discharge a part of it by the urinary passages. Iron is obtained from the red particles of the blood, but not from the washed coagulum. These facts, together with the increased redness of the blood by passing through the lungs, where it may be supposed to suffer a degree of calcination from the absorption of oxygen, render the above opinion highly probable.

The fibrous part of the blood, when thoroughly washed, is white and insipid; by distillation, like other animal matters, it affords water, oil and volatile alkali. Exposed to a gentle heat, it is much hardened; when suddenly exposed to a strong heat, it shrinks up like parchment. It putrefies very rapidly, and affords much volatile alkali. It is insoluble in water, and when boiled in that fluid hardens, and assumes a grey colour. Acids unite with it, and in particular the nitrous acid dissolves it, and extricates azote and nitrous air; while the residue by evaporation affords acid of sugar in crystals, a pecu-

a peculiar oil in flocks, and the phosphoric salt of lime. Marine acid forms a green jelly with the fibrous part of the blood. The acid of vinegar dissolves it with the assistance of heat; water, and more particularly alkalis, precipitate the fibrous matter when dissolved in acids. The animal substance is decomposed in these combinations; and when separated from the acids by any method, it no longer retains its former properties.

The microscopical appearances of the blood have attracted great attention. Various accounts have been published on this subject, most of which seem to have been framed more on theory and preconceived opinion, than actual observation. These falsities have been detected by Mr. Hewson, whose microscopical experiments on the blood are the latest which have been made, and remain at present (as far as relates to the composition of the blood) uncontradicted. I shall therefore transcribe the following particular account of them, given by himself in a letter to Dr. Haygarth, physician, in Chester.

‘ The red particles of the blood, improperly called *globules*, are flat in all animals, and of very different sizes in different animals. In man they are small, as flat as a shilling, and appear to have a dark spot in the middle. In order to see them distinctly, I dilute the blood with fresh serum. My predecessors, not having thought of this, could not see them distinctly. And Lewenhoeck in particular, imagining a round figure fittest for motion, concluded they must be round in the human body; though he and others allowed that in frogs, &c. where they viewed them distinctly, from the blood

being thinner, they were flat. Now I prove that they are flat in all animals. In the human blood, where these particles are small, it is difficult to determine what that black spot is, which appears in the center of each. Some have concluded that it was a perforation; but in a frog, where it is six times as large as in a man, it is easy to shew that it is not a perforation, but on the contrary, is a little solid, which is contained in the middle of a vesicle. Instead, therefore, of calling this part of the blood red *globules*, I should call it red *vesicles*; for each particle is a flat vesicle, with a little solid sphere in the centre.

‘ I find that the blood of all animals contains vesicles of this sort. In human blood there are millions of them, and they give it the red colour; but in insects they are white, and less numerous in proportion than in man and quadrupeds. As they are flat in all animals, I suspect that shape is a circumstance of importance, but can be altered by a mixture with different fluids. And I find, that it is by a determinate quantity of neutral salt contained in the serum, that this fluid is adapted to preserving these vesicles in their flat shape: for if they are mixed with water, they become round, and dissolve perfectly; but add a little of any neutral salt to the water, and they remain in it without any alteration in their shape, and without dissolving.

‘ Now, when it is considered that the blood of all animals is filled with these particles, we must believe that they serve some very important purpose in the animal œconomy; and since they are so complicated in their structure, it is improbable that

that they should be formed by mechanical agitation in the lungs or blood-vessels, as has been suspected, but probably have some organs set apart for their formation. This I shall endeavour to prove, when I have explained their structure a little more particularly, and mentioned the manner in which I exhibit it. I take the blood of a toad or frog, in which they are very large; I mix it with the serum of human blood to dilute it; I find them appear all flat, so they do in the blood-vessels of this animal, as I have distinctly seen in the web between its toes, whilst the animal was alive and fixed in the microscope. Their appearance in these animals is not unlike slices of cucumber. I next mix a little of the blood with water, which immediately makes them all round, and then begins to dissolve them whilst they are round. I incline the stage of the microscope, so as to make them roll down it; and then I can distinctly see the solid in the middle fall from side to side, like a pea in a bladder. A neutral salt added to them at this time brings them back to their flat shape; but if the salt is not added, the water gradually dissolves away the vesicle; and then the little sphere is left naked. Such is the composition of these particles. I have exhibited these experiments to a considerable number of my acquaintance, who all agree in their being satisfactory.

‘ The microscope I use is a single lens, and therefore as little likely to deceive us as a pair of spectacles, which, as is allowed by all who use them, do not disfigure objects, but only represent them larger.’

It is unnecessary to follow Mr. Hewson into his speculations with regard to the use of the thymus and lymphatic glands, which he thinks are designed to fabricate the middle solid particles of the blood which are afterwards to be furnished with vesicles in the cells of the spleen. These inquiries may shew the ingenuity of their author, but will not answer our purpose, which is to detail with conciseness what has been ascertained with certainty.

C H A P. III.

STRUCTURE OF ANIMALS.

Size of Man.—His erect Posture.—Varieties in the Structure of Animals.—Parts of the Animal Body.

IN taking a general view of the formation of MAN, a circumstance of importance is his size, considered in relation to the force of gravitation. If the size of man was much greater than it is, supposing his strength to be only in proportion, his motions would be much slower, and more laborious; nor would his increase of size be entirely compensated by a diminution in the force of gravitation, for this would expose him to inconveniences, on account of the various relations in which he stands to other objects. On the contrary, was man much smaller, though he would gain in celerity what he would lose in force, yet his weakness would incapacitate him for acting with advantage on considerable masses of matter. On the whole, it should seem, that neither an increase of size with an increase of gravitation; nor a diminution of size with a diminution of gravitation; nor an increase of either with a diminution of the other, would in general so well suit the conveniences of man, and his relation

relation to other beings, as the state in which he at present subsists.

The most striking difference of structure between man and the other animals is his erect figure, excellently adapted to the more extensive views which he was designed to take of nature; and which, instead of being a mark, as Helvetius pretends to think, of human arrogance, in departing from the horizontal posture, which was allotted to man in common with other quadrupeds, is one proof of the distance which the Deity meant to interpose between man and the rest of the animal creation. Helvetius, however, denies the superiority of man in every respect; and maintains, that the mental acquirements of a horse would not be inferior to those of a man, if the former was furnished with fingers, and endued with the same exquisite sense of feeling which the latter enjoys. We may grant that all our simple ideas are derived from the information of our senses; but we would ask what experiments Helvetius or his adherents have made, to ascertain, that there can be no differences in the structure of intellectual organs? and upon what authority they conclude, that all the varieties we observe in mental endowments, among individuals of the same race, as well as among different races of animals, are solely to be referred to differences in the organs of sense? But granting all that Helvetius requests, how came man to have fingers and horses none, if they were equally designed to gallop through the forest?—he must either have made fingers for himself, or he must have been originally designed by his Maker for nobler occupations.

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The structure of man, moreover, in several other particulars, entirely confutes the assertions of Helvetius; but without attending to other circumstances, it will be sufficient to mention the formation of the lower extremities in man, so different from the hind legs of quadrupeds, and so admirably adapted to the erect posture. By some naturalists the Ourang-Outang is considered as the original stock of the human race. His claims to humanity are founded upon his being able to walk upright, being furnished with such muscles as are requisite for that purpose. The form of his heart, lungs, breast, brains, and intestines are similar to those of a man. He can sit upright with ease, and can handle a stick with dexterity. That his race is distinct, however, from that of man, is evident, from his having thirteen ribs on each side, whereas man has but twelve. He has not the faculty of speech, and articulation is impossible to him, on account of the structure of the parts about the larynx.

While, however, we dissent from Helvetius, in sinking man to the level of other animals, let us reflect that the purpose of nature seems to be, to diffuse life and enjoyment wherever they can exist; and let us avoid the opposite, narrow-minded, and if possible, still more absurd notion, that the happiness of man is the sole object of creation.

In the animals which more commonly fall under our observation, the surface is soft, and the bones are deeply seated; but in others the reverse happens, and we observe the bones forming a case to the softer parts. We see some animals furnished with wings, to sport in the regions of the atmosphere;

some immerfed by means of a heavy ſhell, during the whole of their exiſtence, in the depths of the ocean; and others furniſhed with organs, to perforate their dark paſſage through the bowels of the earth. In general the bones of animals are filled with marrow, but in many kinds of birds they are excavated for the reception of air, fitting them for floating more eaſily on the ſurface of water, and at the ſame time, when neceſſity requires, for remaining longer beneath its ſurface. In ſome animals, even the brain and heart eſcape our moſt careful reſearches; and ſome, like vegetables, may be multiplied from the limbs of their parents. So endleſs indeed are theſe differences, that there is perhaps no one circumſtance of ſtructure or function common to all animals.—But let us return from theſe extenſive proſpects to the conſideration of the ſtructure of our own ſpecies.

Before we proceed, however, to conſider the ſtructure of the body, it will be proper to premiſe a few very brief definitions of the moſt remarkable parts of which it conſiſts.

Bones are hard ſubſtances, which form the baſis of the body.

Cartilages are firm, ſmooth, elaſtic bodies, which cover ends of the bones.

Muſcles are contractile organs, which are attached to bones, and perform the motions of the body.

Tendons are tough cords, by means of which muſcles are attached to bones.

Ligaments are ſtrong fibres or membranes, which connect bones to each other.

Blood-

Blood-vessels are membranous flexible tubes, which convey the blood to and from the heart.

Lymphatics are transparent tubes, which perform absorption.

Nerves are white cords connected with the brain, and are the instruments of sensation and voluntary motion.

Glands are organic masses, destined for the purpose of secretion.

CHAP. IV.

STRUCTURE OF THE BONES.

Bones consist of Fibres; cellular.—The Marrow.—Waste of Bone in old Age.—Epiphyses.—Periosteum.—Progress of Ossification.—Articulation.

THE body, as Hippocrates long ago remarked, is a circle; and therefore at whatever point we were to begin the description, we should ultimately be equally led, by the connexion of parts, to the consideration of the whole. As the bones, however, may be considered as the basis of the body, on which the other parts depend for situation and support, it appears most eligible in the first place to consider their structure and uses.

The bones consist of fibres, distributed in lamellæ or plates; these plates are not closely applied to each other, but, with the intervention of transverse fibres, constitute cells. The cells are distributed through the substance of all the bones, but are uniformly most remarkable in the centre, and on the surface of the harder bones are so small as not to be distinctly perceptible without the aid of glasses.

The marrow which fills the cavities of the bones is a fat oily substance, contained in a fine and transparent

parent membrane, which receives numerous blood-vessels, and is supported by the filaments of the reticular substance of the bones. If the different parts of a bone are observed, it is found that where the diameter of the bone is the least, there the sides are thickest and most compact; where the diameter is greatest, which is in general towards the ends of the long bones, their structure is very cavernous throughout. The marrow pervades the whole substance of the bones, but is most remarkable in the middle part of the cavities of the long bones. Its appearance and nature also differ in different bones, or in the same bone in the progress of life. Thus the marrow is bloody in children, oily in adults, and thinner and more watery in aged people.

At the time of birth, the bones are very imperfect, particularly those of the head; so that by being moveable in this part, and folding over each other during the time of delivery, an easier passage is procured for the infant. There are many projections from the bones, which in infancy are soft, but which in the adult state are bony; and the same tendency to the formation of bone increasing with our years, bones which were separate in the prime of life concrete in old age. In the decay of the body, however, the bones are diminished with the other parts, so as in extreme old age to weigh a third less than in the middle periods of life.

To far the greater number of bones whose ends are not joined to other bones by immoveable articulation, are annexed, by the intervention of cartilage, smaller bones, called epiphyses or appendages. In young subjects these are easily separable, but in adults

adults the point of conjunction is not very perceptible.

The bones are furnished with a tough membrane, called the *periosteum*, which is spread on their surface, and the principal use of which seems to be to convey blood-vessels for their nourishment; these blood-vessels are very numerous and remarkable in the bones in the infant state, but become gradually less so in the progress of life.

It has been supposed that the bones were formed by successive ossification of layers of the *periosteum*. This opinion, however, is contrary to what is observed on examining bones in the progress of their formation: and is also disproved by some experiments, in which animals were fed with madder. Their bones were found to be tinged in proportion to the length of time that they were kept on this food; but neither the *periosteum* nor the cartilages were altered from their natural colour.

The most general division of the bones is that into the long and cylindrical, and the flat and the broad. The ossification in both these kinds of bones begins in the middle, at several points at a time, and gradually extends towards the ends of the long bones and the circumference of the broad.

The ends of the long bones, where they are united to each other, are larger than their middle part, and several advantages attend this structure. By these means the surface of contact between the two bones of an articulation is increased, their conjunction consequently becomes firmer, there is more space for the connection of muscles, which also act more powerfully from their axes being further removed

moved from the middle of the joint, or the center of motion.

The bones are united to each other, either moveably or immoveably. They are moveably articulated in three ways:—1st. By a ball and socket, which admits of motion in all directions, as in the shoulder. 2dly, By a hinge, which allows motion in only two directions, as in the knee; and 3dly, By a long process of one bone received into the cavity of another, which admits of a rotatory motion, as in the articulation of the first and second vertebræ of the neck. The immoveable articulation of bones is of two kinds: 1st, where numerous processes of two bones, like the teeth of saws, are mutually received into each other, as in the bones of the head; and 2dly, by the growing together of bones with the intervention of cartilage, as in the union of the os sacrum with the ossa innominata.

The ends of bones which move on each other are tipped with smooth cartilage; and the friction is still further diminished by a fluid, much more slippery than oil itself, which is called synovia. The moveable joints are also furnished with strong membranes, called ligaments, which pass from one bone to another, affording strength, and retaining the heads of the bones in their cavities. For the purposes of articulation, and the connection of muscles, bones are uneven on their surface, and have numerous elevations and depressions.

C H A P. V.

DIVISION OF THE SKELETON, WITH THE BONES
OF THE HEAD.

The Skeleton briefly described.—Bones of the Cranium.—Bones of the Face—of the Nose—of the Palate.—The upper and under Jaw.—Form and Proportion of the Head.—Substance and Structure of the Bones of the Head.—Sutures.

THE skeleton, by which is understood all the bones of the body in their proper situations, is divided into the head, trunk, and extremities.

When the bones are put into a natural situation, scarcely any one of them will be found to have a perpendicular bearing on another; though the fabric composed of them is so contrived, that in an erect posture a perpendicular line from the common centre of gravity falls in the middle of their common base. On this account, we can support ourselves as firmly, as if the axis of all the bones had been a strait line, perpendicular to the horizon; and we have much greater quickness, ease, and strength, in several of the necessary motions, as well as other advantages in the situation and protection of the viscera. It is true, indeed, that wherever the bones on which any part of the body is sustained, decline from a strait line, the force of the muscles required to counteract the gravity is greater than
would

would be otherwise necessary; but this is more than compensated by the advantages above mentioned.

The bones of the head are divided into those of the cranium and face. The cranium, or that bony case which surrounds and protects the brain, consists of eight pieces of bone. At the fore part is placed the *os frontis*; at the back part the *os occipitis*; at the upper and side parts the *ossa parietalia*; at the under and side parts, the *ossa temporalia*; in the fore part of the base the *os ethmoides*; in the middle of it the *os sphenoides*. These two latter bones are common to the cranium and face.

The *os frontis* is so called from being the only bone of the forehead, though it extends considerably farther upwards. It has some resemblance in shape to the *concha bivalvis*, commonly called the cockle. The greater part of it is convex externally, and concave internally, with a serrated circular edge. The upper part of the *os frontis*, where it is connected to the parietal bones, is very smooth and convex, but below it has several inequalities, where it contributes considerably to the formation of the cavities, in which the eyes are lodged. In the part of the *os frontis* which corresponds with that part of the forehead immediately above the eye-brows, the two tables of the bone separate by the external being protruded outwards, to form two large cavities, called frontal sinuses. These cavities communicate with the external air by means of the nose. The frontal bone serves to support and protect the anterior lobes of the brain. The falx of the dura mater, of which I shall have occasion to speak
more

more fully hereafter, is attached to a ridge or furrow at the middle and internal part of this bone. The os frontis is pierced with some small holes for the passage of blood-vessels.

Each of the two ossa parietalia is an irregular square, its upper and fore sides being longer than that behind or below. The inferior side is a concave arch; the middle of it receiving the upper and round part of the temporal bone. The external surface of each parietal bone is convex. On their inner concave surface we observe a number of deep furrows, disposed like the branches of trees, which receive the blood-vessels of the dura mater. On the inside of the upper edge of the ossa parietalia, there is a large sinuosity, where the upper part of the falx is fastened, and the superior longitudinal sinus is lodged. The ossa parietalia are the most equal and smooth, and are among the thinnest bones of the cranium; and yet the division of their substance into two tables and a diploe is no where so remarkable. These bones are joined before to the os frontis by the coronal suture; at their long inferior angles, to the sphenoid bone, by part of the suture of this name; at their lower edge, to the ossa temporum, by the squamous suture; behind to the os occipitis, by the lambdoidal suture; and above to one another, by the sagittal suture. In a child born at the full time, none of the sides of this bone are completed, and the brain is in general not completely surrounded by a bony case, till six or seven years of age.

The ossa temporum are equal and smooth above, where they terminate in a thin semicircular edge, which

which is laid over the inferior part of each of the *ossa parietalia*, as the scales of fish are placed over each other, forming a juncture, which is on this account called squamous. Behind this, the upper part of the temporal bone is thicker, and more unequal. Towards the base of the skull, the temporal bone is very irregular and unequal, and becomes contracted into an oblong very hard substance; and being extended forwards and inwards, becomes smaller, and is called the *os petrosum*, which contains the internal parts of the organ of hearing. This bone has three remarkable processes. The first, placed at the lower and posterior part of the bone, is from its resemblance to a nipple called *mastoides* or *mamillaris*. Within it is composed of small cells, which have a communication with the organs of hearing. About an inch farther forward, the second process begins to rise from the bone; and having its origin continued obliquely downwards and forwards, it becomes smaller, and is at length united with a corresponding process of the *os maxillæ*, or cheek-bone. In this manner is formed a bony jugum or yoke, under which the temporal muscle passes. Hence this process of the temporal bone has been called *zigomatic*. From the inferior unequal part of the *os temporum* the third process stands out obliquely forwards; the shape of it has been thought to resemble the ancient *stylus scriptorius*, and it is therefore called the *styloid process*. The chief use of these processes is to afford attachment to muscles. Numerous sinuosities or depressions of this bone, by increasing the surface, answer the same purpose. This bone has also several perforations,

one of which, situated between the zygomatic and mastoid processes, is the orifice of a large funnel or canal, which leads to the organ of hearing.

The os occipitis, so called from its situation at the back part of the head, like the other bones of the cranium, is externally convex, and internally concave. Its figure is an irregular square, or rather a rhomboid; of which the angle above is generally a little rounded; and the lower angle is extended to the inferior part of the cranium, in the form of a wedge, and is thence called the cuneiform process. At the base of this triangular process, on each side of the great foramen, through which passes the spinal marrow, are observed two large oblong processes, called the condyles, which serve for the articulation of the cranium with the first vertebra of the neck. Around the great foramen, the edges are unequal, for the firmer adhesion of the strong circular ligament which passes from the circumference of the foramen to the first vertebra. On the inside of the occipital bone are several ridges and furrows; to one of the ridges is fixed the posterior part of the falx, and the furrows receive the sinuses which run in this part of the cranium. The ridges of this bone form a cross, and round the middle of the cross there are four large depressions, separated by its limbs; the two upper depressions being formed by the posterior part of the brain, and the two lower by the cerebellum. The inner surface of the cuneiform process is hollowed for the reception of the medulla oblongata and the basilar artery. Besides the great foramen, there are several other perforations in this bone,

bone, or between it and the adjoining bones, for the passage of nerves and blood-vessels. The occipital bone at its upper part, where it is chiefly exposed to injury, is very thick and strong, but lower down, where it is protected by the strong and thick muscles which are inserted into it, it is often very thin. The occipital bone is connected above to the ossa parietalia by the lambdoidal future; laterally to the temporal bones by a continuation of the same future; below it is firmly connected by an union of substance to the sphenoid bone, by means of the cuneiform process.

The os ethmoides, or sieve-like bone, derives its name from the numerous small apertures with which it is pierced at its fore part. From the middle of the internal side of the lamella, which is so full of holes, a thick process rises upwards; and being highest at the fore part, gradually becomes lower as it is extended backwards. From a fancied resemblance of this process to a cock's comb, it has been called the crista-galli. The falx is connected to its ridge, and to the unperforated part of the cribriform plate. All the prominences, cavities, and meanders of the ethmoid bone are covered with a continuation of the membrane of the nostrils. The uses of this bone are to sustain the anterior lobes of the brain; to give passage to the olfactory nerves, and attachment to the falx; to enlarge the organ of smelling, by allowing the membrane of the nose a greater extent; to form a part of the orbit of the eyes, and the septum varium.

The os sphenoides, or wedge-like bone, which is so called from its situation in the middle of the

bones of the cranium and face, is of a very irregular figure, and bears some resemblance to a bat, with its wings extended. This bone is generally divided into a body, and two sides or wings. When we view the external part of the *os sphenoides*, two or three remarkable processes from each side of it may be observed, which are all of them again subdivided. The first pair consists of the two large lateral processes or wings; the upper part of each of which is called the temporal process, because they join with the temporal bones in forming the temples: that part of the wings which projects towards the inside, somewhat lower than the temporal processes, and is smooth and hollowed, forms part of the orbits. The lowest and back part of each wing runs out with a sharp point, called the spinous process, to meet the point of the *pars petrosa* of the temporal bone. The second pair of external processes of the sphenoid bone are the aliform or pterygoid, and which stand out almost perpendicular to the base of the skull. Each of them has two plates and a middle fossa at the posterior surface. Of these plates, the exterior is the broadest; the interior are longest, and terminate in a hook-like process. Another pair of processes may be mentioned, viz. the little triangular thin processes which come from each side of the sphenoid bone, where the pterygoid processes rise from it; these are extended to join the ethmoid bone. The external surface of this bone is every where covered with depressions, sinuosities, and fossæ. Within there are three remarkable fossæ; two of these are seated in the internal part of each wing
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of the sphenoid bone, for receiving the middle part of the brain. The third, which is smaller, is seated on the top of the body of the bone, which from its resemblance to a Turkish saddle is described under the name of *sella turcica*. In this fossa a gland called the pituitary is placed; behind and before it are the clinoid processes. The holes on each side of the *os sphenoides* are six proper and three common. The first is a round aperture, immediately below the anterior clinoid processes, which transmits the optic nerve and ocular artery. The second, which is a large slit, and is called the *foramen lacerum*, transmits the third, fourth, sixth, and the first branch of the fifth pair of nerves. The third hole, situated a little lower, is called *rotundum* from its shape, and transmits the second branch of the fifth pair of nerves. The fourth is the *foramen ovale*, about half an inch behind the *foramen rotundum*; through it passes the third branch of the fifth pair. Very near the point of the spinous process is the fifth hole of this bone, which is small and round, and gives passage to the largest artery of the *dura mater*. The sixth proper hole cannot well be seen till the cuneiform bone is removed from the other bones of the cranium—for one end of it is hid by a small protuberance of the internal plate of the pterygoid process, and by the point of the *processus petrosus* of the temporal bone. Through it a considerable branch of the fifth pair of nerves is reflected. The first of the common apertures is that unequal fissure at the side of the *sella turcica*, between the extreme point of the *os petrosum* and the spinous process of the

cuneiform bone. This perforation only appears after the bones are boiled; for in a recent subject, its back part is covered by a thin bony plate, which lies over the internal carotid artery, and farther forward it is filled with a cartilaginous ligament, under which the cartilaginous part of the eustachian tube is placed: it was by this passage that the ancients believed the slimy matter was conveyed from the glandula pituitaria to the fauces. The second aperture is a large discontinuation of the external side of the orbit, left between the orbitar processes of the sphenoid bone, the os maxillare, malæ, and palati. The third common aperture is formed between the base of this bone and the root of the orbitar process of the palate bone of each side.

Under the fella turcica, within the substance of the sphenoid bone, are two sinuses, separated by a bony plate, which are lined with a membrane, and open into the nostrils.

The sphenoid bone is joined to all the bones of the cranium, and likewise to the ossa maxillaria, ossa malorum, ossa palati, and vomer.

The face is divided into the upper and under maxillæ or jaws. The upper jaw is the immovable part of the face, which consists of six bones on each side, and a thirteenth in the middle. The thirteen bones are two ossa nasi, two ossa unguis, two ossa malarum, two ossa maxillaria, two ossa palati, two ossa spongiosa inferiora, and the vomer. The ossa nasi are placed at the upper part of the nose; the ossa unguis are the internal canthi of the orbits; the ossa malarum form the prominence of the

the cheeks; the ossa maxillaria form the side of the nose, with the whole lower and fore part of the upper jaw, and the greatest part of the roof of the mouth; the ossa palati are situated at the back part of the palate, nostrils, and orbit; the ossa spongiosa are seen in the lower part of the nostrils; and the vomer helps to separate these two cavities. The bones of the face, besides being connected to the bones of the cranium by sutures, common to them with the bones of the cranium, are joined to each other by fifteen sutures, which it would be tedious to describe. Neither does a description of the form and connection of each of these small bones fall in with the general view of the structure of the body which I propose to take.

The lower jaw in the adult consists of only one bone. In form, it resembles a horse-shoe, the convex part of which is turned forwards, and forms the chin. At its back part this bone is bent upwards, and terminates in two processes. The anterior of these, which rises highest, is a thin point, into which muscles are inserted. The posterior process terminates in an oblong smooth head tipped with cartilage; it is called the condyloid, and is received into a fossa of the temporal bone, where it is capable of very extensive motion. There is a cavity through the substance of this bone, which receives a large twigg of the third branch of the fifth pair of nerves. This begins at the bottom of each coronoid process, and terminates externally near the chin. This bone is fur-

nished with an outer and inner bony plate, called the alveolar processes, for retaining the teeth with firmness. In each of the jaws are placed sixteen teeth; so that the head, if we include the os hyoides, a small bone situated under the chin, consists in the adult of sixty-three pieces.

With respect to the form of the cranium, when seen from above, and when the forehead is placed next the eye, it very much resembles that of an egg; the os frontis corresponding to the smaller end of it, and the os occipitis to the greater. When seen in any other point of view, however, this resemblance is not perceptible. The sides of the head are flat, and the lower part is flat and irregular. The bones of the face constitute an imperfect triangle. The size of the head, in a well-formed person, is to the rest of the body as one to nine.

The substance of the bones of the cranium is in general made up of two tables or plates, with the interposition of a spongy cavity. The external table is thicker, smoother, and covered with the periosteum; the internal is thinner, more uneven, more brittle, and is lined with a thick vascular membrane, called the dura mater.

The bones of the head are united to each other by a number of tooth-like processes; and these joinings are called sutures. The coronal suture runs across the head, and connects the frontal bone to the parietal bones. The sagittal suture divides the upper part of the head into two equal parts. It connects the two parietal bones to each other, and passes from the middle of the frontal to the middle of the occipital bone.

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The lambdoid suture is interposed between the back and fore parts of the cranium, or between the occipital and two parietal bones. The two squamose sutures connect the temporal bones to the parietal. There are also many less remarkable sutures, which join the bones of the face to those of the cranium.

CHAP. VI.

THE TEETH.

General Description of the Teeth.—Incisores.—Canini.—Molares.—Enamel of the Teeth.—Growth of the Teeth.—The Face lengthened after Eight Years of Age.—Varieties in the Teeth of different Animals.

THE teeth, both of the upper and lower jaw, are fixed in sockets of the jaw-bones, formed of thin bony lamellæ. That part of the teeth which projects beyond the gums, is called their body; the external termination of the body, the corona or crown; and that which is hid, and which terminates in a wedge-like point, is called the radix or root. The roots of the teeth are perforated at their extremities, for the reception of nerves and blood-vessels.

The teeth are divided into three orders. The four front cutting teeth, are called incisores. Next to these is placed on each side a tooth, called from its form the canine or dog-tooth; and lastly, on each side five molares or grinding teeth. The last tooth on each side, from its not being cut till after the age of puberty, is also called dens sapientiæ, or the tooth of wisdom.

The four incisores are smaller and narrower in the lower than in the upper jaw. The corona of
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the incisores is broad and sharp, and in children is much notched. The roots of the incisores are short, and terminate in a single blunt apex. The canine teeth are stronger, more acute, and more deeply rooted than the incisores. They are convex before and concave behind, and are fitted for tearing our food to pieces. The molares, by the eminences on the corona, and by their broad upper surfaces, are evidently, as their name expresses, designed for the grinding of the food. The anterior molares are smaller and less uneven on the corona than the posterior; the strongest being placed nearest the articulation of the jaw-bone, because there we can exert the greatest force. The roots of the molares are long and pointed; each tooth has two, three, four, and sometimes, though very rarely, five roots. The roots sometimes stand separate, sometimes are concreted together; sometimes they are strait, sometimes crooked.

The substance of the teeth is compact. The corona is covered with a curious substance, called the enamel. This is thin, white, shining, and, being the hardest and most compact substance in the body, is admirably adapted to the purposes of mastication.

It is scarcely necessary to remark, that in eating we only move the lower jaw, and that the upper is on all occasions fixed and immoveable.

In the infant state, two sets of teeth are already observable in the jaw-bones. In the cutting of the teeth, the incisores first make their appearance, in general about the eighth month; and afterwards, at about two years of age, two molares and the
dog-

dog-tooth. The first set of teeth when complete is but twenty in number, viz. eight incisores, eight molares, and four canini. In the second set are added twelve molares, viz. three on each side in each jaw, making the complete set in the adult thirty-two. To make room for this addition, the jaws undergo a gradual elongation. Hence the face is so much lengthened from eight to eighteen years of age. About the seventh-year the second set begins to supply the place of the first, which by this time become loose, by the waste of the sockets and the growth of the teeth below.

If we extend our views to the lower animals, we shall find no part of the body more various among different races than the teeth. This circumstance is so remarkable, that Linnæus has employed it in the distribution of the first class of animals (the mammalia) into its several orders. To enumerate all the varieties of teeth would be impossible, and at present it would be superfluous. Let it be remarked, however, that they are not without their uses, and that every animal experiences the advantages of its own peculiar structure.

CHAP. VII.

BONES OF THE TRUNK.

Spine or Back Bone.—How the Head is moved.—The Thorax.

—The Pelvis.—Principal Marks of Distinction between the Male and Female Skeleton.

THE bones of the trunk are divided into those of the spine or back-bone, the thorax or chest, and the pelvis. The spine consists of twenty-four pieces of bone called vertebræ; seven of these belong to the neck, twelve to the back, and five to the loins. The thorax consists anteriorly and laterally of twelve ribs on each side of the sternum or breast-bone, and part of the spine behind. The pelvis is composed of four bones; two ossa innominata or hip-bones; the os sacrum, and the os coccygis.

That series of bones called the spine forms a column larger below than above, smooth and round before, very rough and uneven behind, and hollow within. The bones of the spine are joined to each other by cartilages, in the centre of each of which is contained a fluid; a curious circumstance of structure first discovered by the late Dr. Monro, of Edinburgh. The chief advantage of this structure is, that this fluid, when confined, has all the resistance of a solid body, without its hardness, which in this part might be attended with very bad consequences.

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The head is connected to the upper vertebra of the neck by two smooth projections of that vertebra, which are called condyls, being received into two corresponding cavities in the under part of the cranium. By means of this joint we move the head backwards and forwards on the spine, or perform the action of nodding. As it is necessary, however, for the head to have also a rotatory motion, we here find a peculiarity of structure to which there is nothing similar in any other part of the body. In the upper surface of the second vertebra of the neck there is a long tooth-like process or projection, which is received into a perforation of the first vertebra. This process is rendered smooth by a covering of cartilage; it passes quite through the vertebra above it, and is connected to this as well as to the cranium by strong ligaments, which give strength to the connection, and guard against the effects of a too extensive motion. The rotatory motions of the head, therefore, are not performed on the first vertebra of the neck, but on the second; the first vertebra, with the head, moving on the tooth-like process of the second vertebra, as a wheel moves on its nave.

The spine, however, though it forms a column, does not form by any means an upright column. The spine, viewed sideways, if the os sacrum is considered as a continuation of it, is bent very much in the form of the letter *s*. In the neck it projects somewhat forwards, lower down it takes a curved direction backwards, to make room for the heart and lungs. In the loins it advances again forwards under the centre of gravity, so as to support

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port the abdominal viscera; and in the pelvis it recedes backwards, so as considerably to enlarge that cavity.

Each vertebra is divided into a body and seven projections, apophyses or processes. The body is placed before, it is smooth, of a roundish form, and a remarkably spongy texture. The processes are of a much firmer texture, and project backwards. Two of these processes are called the superior oblique, and ascend obliquely from the upper part of the vertebra; two are called the inferior oblique, and descend obliquely from the lower part; two are called the transverse, and project sideways; and one is called the spinous, from its resemblance to a thorn, which projects directly backwards. Of these processes the spinous and transverse are the most prominent. The oblique processes seem chiefly designed for the articulation of the vertebræ with each other, and are therefore also called articular processes. All the vertebræ are perforated for the reception of the spinal marrow, and also have notches for the transmission of nerves.

The uses of the spine are to support the body in an erect posture, and at the same time, by the number of joints with which it is furnished, to admit of a free motion, without danger of compressing the spinal marrow, which it is designed to protect. It is formed larger below than above, because the lower parts of it have a greater weight to support than the upper; and because, when the body is bent, that weight acts with the longest lever against that part of the spine which is farthest removed from it.

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In very young children, each vertebra consists of three pieces of bone united by cartilage. As the spine contains so important a part as the spinal marrow, we observe a solicitous care taken by Providence, that the vertebræ should not be disjoined. Besides being connected by strong ligaments, proportioned to the forces which are to be resisted, the vertebræ of the neck enter into each other, those of the back are propped by the ribs, and those of the loins have so large a surface of contact, as to render their separation almost impracticable.

The thorax is a bony cavity, narrow above, wide below, and arched behind and at its sides.

The sternum or breast-bone, which forms the anterior part of the thorax, is of a spongy consistence, and of a flat and nearly triangular form; in infancy it consists of many parts, in the adult state of only two, or sometimes three. The upper part is broad and thick, the lower narrow and thin. The lowest part of the sternum, from its resemblance to a dagger, and its cartilaginous nature, is called *cartilago ensiformis*. The upper part of this bone is notched for the passage of the wind-pipe, and there are two cavities in its sides for the articulation of the clavicles or collar-bones. There are also seven small holes on each side, for the articulation of seven ribs. Its uses are to support the ribs, to protect the lungs and heart, and to furnish connection to a muscular organ, which will be afterwards considered, called the diaphragm.

The ribs which constitute the greater part of the cavity of the thorax, are somewhat of a semicircular form; they pass from the spine towards the sternum; they

they are not connected, however, to the vertebræ themselves, but to the cartilagino-ligamentous substance which connects the vertebræ to each other. At the posterior part the rib has two processes; one of these, by which it is connected between two vertebræ, is called its head; another is articulated with the transverse process of the vertebræ immediately below, and is called its tuberosity. Advancing farther on this external surface, we observe on most of the ribs another smaller tubercle, into which ligaments connecting the ribs to each other, and to the transverse processes of the vertebræ, and portions of the longissimus dorsi, are inserted. Beyond this the ribs make a considerable curve, sometimes called their angle. The ribs then begin to become broad, and continue so to their anterior end, whereas near the spine they are nearly round. To the fore end of each rib a long broad and strong cartilage is fixed, and reaches thence to the sternum, or is joined to the cartilage of the next rib. The ribs are twenty-four in number, twelve being placed on each side. They are divided into the true and the false ribs; the seven uppermost on each side, which are connected to the sternum, being called *true*, and the remaining five *false*.

The upper rib is so placed, that its connection with the sternum is somewhat higher than that with the spine, and the two connections of the second rib are about horizontal; all the other ribs, however, point obliquely downwards, as they approach the sternum, and this obliquity increases as we advance lower. A necessary consequence of this structure is, that when the ribs are raised, they must

be brought nearer to a right angle with the spine, and that the cavity of the chest must be enlarged. The upper rib is fixed, but the second and every succeeding rib is gradually more moveable than that placed immediately above it.

The seven upper ribs, called the true ribs, are, as was before remarked, connected to the sternum; the three upper of the false ribs are not connected to the sternum, but adhere to each other, and to the cartilaginous anterior part of the lowest of the true ribs. The two lowest of the false ribs are only connected to the spine by one articulation, and have their other end no otherwise supported than by the muscles and membranes with which they are surrounded. By this structure the trunk of the body is rendered more flexible at its lower part, where most motion is required.

The uses of the ribs are to form the lateral parts of the thorax; to render the cavity of the thorax larger or smaller in breathing; to protect the viscera of the thorax; to give origins and insertions to a variety of muscles; and to support the mammæ or breasts.

The pelvis, so called from its resemblance to a basin, constitutes the lowest part of the trunk. Its posterior part is formed by the os sacrum, and its lateral and anterior parts by the ossa innominata.

The os sacrum may be considered as a continuation of the spine; and some anatomists have called both this bone and the os coccygis by the name of the false vertebræ. The os sacrum is a large thick bone, of a triangular form; its broadest part

is placed uppermost, and its narrowest is turned downwards and inwards. The posterior surface of this bone is convex, the anterior concave. The two lateral margins of it are incrusted with cartilage, by the help of which it is immoveably connected with the ossa innominata. In the middle of this bone there is a canal for the spinal marrow, corresponding with that in the vertebræ of the spine; and on the anterior surface there are ten perforations, for the passage of as many nerves. On the posterior part there are many protuberances, which, like the processes of the vertebræ, serve for the insertion of muscles.

The os coccygis is a small bone of a pointed shape, adhering to the lower part of the os sacrum. The os coccygis is in infancy composed of several pieces of bone, which coalesce, however, in the adult state. It may be considered as a continuation of the os sacrum, and is bent in the same direction with that bone.

The ossa innominata, which form the sides and fore part of the pelvis, are two large broad bones, which in infancy consist each of them of three distinct pieces; but as we advance in life, the intermediate cartilages gradually ossify, and the marks of the original separation disappear, so that they become one irregular bone. They still, however, retain the names of ileum, ischium, and pubis, by which their divisions were originally distinguished, and are described as three different bones, by the generality of anatomists. The ossa innominata are connected posteriorly to the os sacrum, by a firm cartilaginous substance.

The os ileum or haunch-bone, forms the highest and most considerable part of the os innominatum. The external side of the ileum is unequally convex, and is called its dorsum: the internal concave surface is by some authors named its costa. The semicircular edge at the highest part of this bone, which is tipped with cartilage in the recent subject, is named the spine. This has two considerable projections; one anterior, and the other posterior, which is the larger of the two. These ends of the spine being more prominent than the surface of the bone below them, are therefore called anterior and posterior spinous processes. Below the anterior spinous process another protuberance projects, which by its situation may be distinguished from the former, by adding the epithet of *inferior*. Between these two anterior processes, the bone is hollowed. Below the posterior spinal process a second protuberance of the edge of this bone is also to be observed, which is closely applied to the os sacrum. Under this last process a considerable niche is observable in the os ileum; between the sides of which and the strong ligament which is stretched over from the os sacrum to the sharp-pointed process of the os ischium of the recent subject, a large hole is formed, through which the musculus pyriformis, the great sciatic nerve, and the posterior crural vessels, pass, and are protected from compression. The internal surface of the os ileum is concave in its broadest fore part, whence a small sinuosity is continued obliquely forwards, at the inside of the anterior spinous process. This ridge is continued from the os sacrum, and corresponds with a similar prominence,

minence, both of that bone and of the ischium, and forms, with the inner part of the os pubis, what is called the brim of the pelvis. The posterior and lower parts of the ossa ileum are thick ; but at their middle, where they are exposed to the actions of several strong muscles, and to the pressure of the abdominal viscera, they are exceedingly thin and compact.

The ossa ischii or hip bones, form the lower and lateral parts of the pelvis : each is commonly divided into its body, tuberosity and ramus. From the body of the ischium the sharp spinous process stands out back wards, to which the anterior or internal sacrosciatic ligament is fixed. Between the upper part of the ligament and the bones, it was formerly observed that the sciatic nerve, &c. pass out of the pelvis. The tuberosity, or lowest part of the ischium, is large and irregular, affords an origin to several muscles, and is the part on which the body rests in the posture of sitting. From the tuberosity the bone becomes thinner and narrower ; and passing forwards and upwards, concurs with the ramus of the os pubis, to form a large hole, called foramen magnum ischii, or thyroideum. This hole, which in the recent subject is closed with a strong membrane, called the obturator ligament, affords through its whole circumference attachment to muscles.

The ossa pubis constitute the anterior, or, when the body is erect, the lower part of the pelvis. They are of an irregular form, and as well as the other parts of the ossa innominata have a share in forming the acetabulum. The two ossa pubis are joined together by cartilage at the fore part of the

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pelvis, which is called the symphysis pubis. In each os pubis we may observe the body of the bone, its angle, and ramus. The body or outer part is united to the os ileum; the angle comes forwards to form the symphysis, and the ramus is a thin process which unites with the ramus of the ischium to form the foramen thyroideum.

The acetabulum, or socket of the thigh bone, which is partly formed by all the three bones which constitute the ossa innominata, is placed at the under part of the pelvis, and is turned obliquely outwards. The acetabulum is not a perfect circle in the skeleton, the under part being supplied in the recent subject by cartilage.

The os pubis constitutes about one-fifth of the acetabulum, the os ileum makes something less than two-fifths, and the os ischium as much more than two-fifths.

The pelvis has two openings, one above and one below; that above, when we stand in the erect posture, pointing nearly directly forwards, that below, nearly directly backwards.

The chief differences between the male and female skeletons are in the proportions of the bones of the pelvis. The cavity of the male pelvis is an irregular circle; that of the female is much larger, and of an oblong shape; the longest diameter being from side to side, and the shortest from the os sacrum to the ossa pubis. Hence women are much wider across the hips, in proportion to their height, than men. The os sacrum is broader, and turned more backwards for enlarging the pelvis. The os coccygis is more moveable, and much less bent forwards, to facilitate delivery. In consequence of
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the pelvis being wider in women, the articulations of their thigh-bones must be farther removed from each other, which gives them a different gait from men in running, as they must throw the weight of their bodies further from side to side in order to bring it over the centre of gravity. The bones in general are much finer and less robust in the female than in the male skeleton, and the collar-bones are less curved. The ossification of some of the bones is also in women less complete.

The principal uses of the pelvis are to form an arch between the trunk of the body and the lower extremities; to contain and protect the urinary bladder, the lower part of the intestinal canal, &c.

C H A P. VIII.

THE BONES OF THE INFERIOR EXTREMITY.

The Os Femoris.—Bones of the Leg.—The Foot.

THE bones of the lower extremities are divided into the thigh-bone, the bones of the leg, and the bones of the foot.

The os femoris, or thigh-bone, is the longest bone in the body, and is the largest, thickest, and strongest of the cylindrical bones. The lower extremities are connected to the trunk by the head of the os femoris being received into the acetabulum. The thigh-bone is not placed in a perpendicular direction, the upper ends of the thigh-bones being much further apart than the lower; and from the greater width of the pelvis in women, this difference is much more remarkable in them than in men. The body of this bone is somewhat of a triangular form; it is convex before and flat behind, and is marked particularly behind by bony ridges, which serve for the connection of muscles. This bone is perforated at one or two places for the reception of blood-vessels.

The os femoris is not a straight bone, but is arched considerably forwards. Its head is turned inwards, and the neck is almost horizontal, considered

sidered with respect to its situation with the body of the bone. Throughout two thirds of the length of the thigh-bone, at its posterior part, we observe a ridge called the *linea aspera*, which originates from the trochanters, and after running some way, divides into two smaller ridges, which terminate at the condyls.

The head of the *os femoris* is nearly round, and is marked in the centre with a round pit, into which a ligament, which served to keep it fixed in the socket, was inserted. The neck is narrower above and thicker below, and is terminated by a ridge, to which the capsular ligament of the joint was attached. Below this ridge are two remarkable processes called the trochanters. The larger of the trochanters is directed outwards, and is placed at the outer side of the thigh-bone; the other is placed behind, but points inwards. The surfaces of both the trochanters are very rough, for the insertion of muscles. From the muscles inserted into these two processes being the principal instruments of the rotatory motions of the thigh, they are called trochanters.

The lower extremity of the thigh-bone is thick, and terminates in two condyls*, which are very close to each other before, but considerably removed behind, where there is formed a safe canal, through which a large artery passes to arrive at the leg. Behind are also two cavities which receive ligaments crossing each other for strengthening the connection of the *os femoris* with the larger bone of the leg.

* By the word *condyl* is meant the large extremity of a bone, resembling the knob of a clubbed stick.

The os femoris is united to the trunk by that kind of joint which admits of motion in all directions; but here this motion is in some directions much limited by the capsular ligament of the joint. The substance of this bone, as of all the cylindrical bones, is firm in the middle, and spongy towards the extremities.

The leg has three bones, the tibia, the fibula, and the patella. The tibia, which is the principal bone of the leg, is a cylindrical bone of a triangular form, larger above than below. The upper end of the tibia is large, bulbous, and spongy, and is divided into two cavities by a rough irregular protuberance, which is hollow at its most prominent part, as well before as behind. The two broad cavities at the side of this protuberance are not equal; for the internal is oblong and deep, for receiving the internal condyl of the os femoris; while the external is more superficial and rounder, for the external condyl. The circumference of these cavities is rough and unequal, for the firm connection of the ligaments of the joint. In this manner is formed a hinge or joint, which admits of motion in only two directions. At the back part of this bone the same canal is continued between the condyls, for transmitting blood-vessels and nerves, as in the os femoris; and there are two eminences for the insertion of the other ends of the crucial ligaments. At the anterior part of this bone is a cavity for the reception of the patella, which corresponds with one between the condyls of the os femoris. Below the external edge of the upper end of the tibia is a flat surface of cartilage, for the
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the connection of the fibula; and at its lower end there is a longitudinal cavity on the outside, for receiving the lower part of the same bone. On the internal part of the bottom of the tibia is a process, which forms the inner malleolus or ankle-bone. Still lower, at the extremity of the tibia, is a transverse articulating cavity, covered with cartilage, and divided by a ridge, which receives a bone of the foot called the astragalus. The body of the tibia has three angles, and as many flat surfaces. One of the flat surfaces is turned directly backwards, and one of the angles is placed directly at the fore-part of the bone, and is that sharp ridge which is felt by the finger, being only covered by the common integuments of the body. Another angle is called the posterior and internal, and terminates in the inner ankle-bone; and the third is called the posterior and external angle, and gives connection to the interosseous ligament, which passes from this bone to the fibula.

The fibula, which is nearly opposed to the last-mentioned angle of the tibia, is a triangular and very thin bone, nearly as long as the tibia. Its superior extremity is united to the head of the tibia by means of cartilage. Its head does not rise quite so high as that of the tibia, and has therefore no connection with the os femoris; its lower extremity is slightly connected to the astragalus, and forms the external ankle. Its chief uses are to afford room for the connection of muscles, to extend the interosseous ligament, and to give greater firmness to the connection of the tibia with the foot.

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The patela, rotula, or knee-pan, is a small flat bone of a somewhat triangular form, which is placed at the fore part of the leg, where the tibia is connected with the os femoris. The anterior convex surface of the patella is pierced by a great number of holes, into which enter fibres of the strong ligament which is spread over it. Behind, its surface is smooth, covered with cartilage, and divided by a middle convex ridge into two cavities, both of which are exactly adapted to the pulley of the os femoris. The substance of the patella is cellular, but the cells are so small that it is a very strong bone. Its uses are to protect the joint, and to answer the purpose of a pulley to the muscles which extend the leg.

The foot is composed of the bones of the tarsus, metatarsus, and toes. It is convex above, concave below, and has a considerable projection behind.

The tarsus, which is connected with the bones of the leg, consists of seven pieces of bone, the astragalus, the os calcis, the os naviculare, the os cuboideum, and the three ossa cuneiformia. The astragalus occupies the posterior and upper part of the foot, and is the bone on which the bones of the leg immediately depend for support. The os calcis forms the projection of the heel; it is of a very irregular form, and is divided into the body, which points backwards, and an anterior process by which it is connected with the astragalus and the os cuboideum. The os naviculare is placed before the astragalus, and towards the inside of the foot; it derives its name from its supposed resemblance to a boat. The os cuboideum is placed before the os calcis,

calcis, and towards the outside of the foot. The three ossa cuneiformia are placed before the os naviculare, near to each other, and are so called from their appearing like wedges driven in among the other bones of the foot. The substance of the ossa tarfi is spongy, and they are so connected together by cartilage as not to admit of much motion upon each other.

The metatarsus consists of five cylindrical pieces of bone, interposed between the tarsus and the bones of the toes. Their upper surface is convex, their lower surface concave; their posterior extremity is concave where they are connected with the tarsus, and their anterior extremity is furnished with condyls, by which they are fastened to the bones of the toes.

The bones of the toes are connected to those of the metatarsus. The great toe has only two joints, the rest three, and in this respect they resemble the fingers and the thumb. There are sometimes found small bones, which are called ossa sesamoidæ; these chiefly occur between the first and second joints of the great toe and thumb, and as they answer the same purposes, viz. that of removing the tendon further from the axis of motion, may be considered as small patellæ. They are almost exclusively found in persons advanced in life and inured to hard labour, and therefore are by some supposed to owe their origin to friction.

C H A P. IX.

THE BONES OF THE SUPERIOR EXTREMITY;
WITH A BRIEF COMPARISON OF THE HU-
MAN SKELETON WITH THAT OF BRUTES.

Bones of the Humerus.—Os Bracchii.—Antibracchium.—Bones of the Hand.—Resemblance between the superior and inferior Extremities.—Comparison between the Human Skeleton and that of Quadrupeds.

THE superior extremity is divided into the humerus or shoulder; the brachium or arm; the antibrachium or fore-arm; and the manus or hand.

The humerus is composed of two bones, the scapula or shoulder-blade, and the clavícula or collar-bone. The point where these two bones unite is the top of the shoulder. The scapula is a flat thin bone of a triangular shape. It is situated at the upper part of the back, and extends from the first to about the seventh rib. One of the surfaces of the scapula, which is concave, is applied to the trunk of the body; the other, which is convex, and more uneven, is turned outwards; so that the form of the bone may be plainly discerned in the living person. The external surface is divided by a projecting ridge of bone, called the spine of the scapula, into two parts, the upper of which is much narrower and smaller than the lower. The scapula has three angles,

gles, and three sides or margins. With respect to the margins, that which is placed next the spine is by far the longest, and is therefore sometimes called the base of the scapula; that which forms the upper part of the bone is nearly horizontal, and is parallel to the second rib, and is the shortest and thinnest; the remaining margin, which descends obliquely from the point of the shoulder to the inferior angle, is by far the thickest and strongest.

The processes of this bone are the coracoid, so called from its resemblance to a crow's beak, which rises from the anterior part of the superior margin of the scapula; and the acromion, which is a broad and flat process of the spine, placed at the top of the shoulder, and is the whole thick bulbous fore part of the bone. Near the fore part of the superior margin is a semilunar niche, from one end of which to the other a ligament is stretched; and sometimes the bone is continued to form one or two holes for the passage of the scapular blood-vessels and nerves. From the niche to the termination of the fossa (in which a muscle called the teres major is attached) the scapula is narrower than any where else, and this part has therefore been called its neck.

The cavities of the scapula are the glenoid cavity, wider below than above, and covered with cartilage for the reception of the bone of the arm; and several smaller cavities for the connexion of muscles, and other uses.

The texture of the scapula is firm, but the bone is so thin as at most places to be transparent. It is connected by a ball and socket to the bone of the arm; by the intervention of cartilage to the clavicle;

clavicle; and with the head, the os hyoides, the sternum, the ribs, and the back-bone, by means of muscles. Its uses are for the articulation of the arm-bone, for the insertion of a great number of muscles, to add force and extensiveness to the motions of the arm, and to be a defence to the posterior part of the trunk.

The clavícula, clavicle, or collar-bone, is a cylindrical bone, placed almost horizontally between the side of the sternum and the acromion of the scapula. Its figure is somewhat like that of the letter *f*; and it received its name from a supposed resemblance to the key used among the ancients. The clavicle, as well as other long cylindrical bones, is larger at its ends than at its middle. The end next the sternum is triangular: the angle behind is considerably protruded, to form a sharp ridge, to which the transverse ligament, extended from one clavicle to the other, is fixed. It is for the most part convex without, and concave within. One end of the clavicle is connected by a ball and socket with the sternum, and the other by cartilage to the acromion of the scapula. Its uses are to support the shoulder and other parts of the superior extremity, to protect some large vessels in their passage to the arm, and to connect the scapula to the thorax.

The os brachii, or as it is sometimes called the os humeri, is a cylindrical bone, the round head of which is received into the glenoid cavity of the scapula. It is larger and rounder at its upper part, and smaller and flatter below. It has three projecting lines, and as many flat surfaces, by which form it admits of a more advantageous and extensive

five connexion of muscles, than if it had been a simple cylinder, which is not to be found in any bone of the body, though all the long bones approach to it. This bone has many circumstances of structure in common with the os femoris. Like that bone it is articulated by a round head, which is surrounded by a capsular ligament, and, like it, has processes for the connexion of muscles; but these processes are much less remarkable in the os humeri than in the os femoris. At the lower extremity of this bone we observe several processes and cavities. The most remarkable processes are the two condyls; of these the external is the smallest, and is of an irregular oblong shape. The internal is more protuberant, and serves, as well as the former, to give origin to many muscles. Between these two condyls are two lateral protuberances, which, together with a middle cavity, form a kind of pulley, on which the motions of the fore-arm are chiefly performed.

The antibrachium, or fore-arm, consists of two bones, the ulna and the radius. The ulna, which is the longer of the two bones, and is that by which the fore-arm is chiefly connected with the arm, is large above and small below, and is of an irregular cylindrical form. At the superior extremity of the ulna there are two processes, a larger one called the olecranon, placed posteriorly, and a smaller, called the coronoid, at the anterior part. At the upper end of the ulna, between these processes, is a cavity divided by a projecting line, and covered with smooth cartilage, for the reception of the corresponding projections of the os humeri. There is another cavity

at the side of the coronoid process, covered with cartilage, on which the superior end of the radius rolls in some of the motions of the hand. At the lower extremity of the ulna, which is much smaller than the upper, is a head with a slight excavation, and a small process called the styloid, which forms a projection at the lower end of the fore-arm, on the same side with the little finger, not unlike the ankles. The ulna is firmly connected above, by a hinge joint, to the os humeri, laterally to the radius, and slightly below to the carpus, and its articulations are every where firmly secured with ligaments.

The radius is a bone of nearly the same form, size, and appearance, with the ulna. As the larger end of the ulna is firmly connected with the os humeri, so that of the radius is connected to the carpus. On the contrary, the connections of the ulna with the carpus, and of the radius with the os humeri, are very inconsiderable; the smaller end of the one bone being opposed to the larger of the other, and depending on it for support and firmness. The ends of these two bones are closely joined together; their middle parts recede from each other, with the interposition of an interosseous ligament, similar to that between the tibia and fibula. At the upper end of the radius is a small cavity, which receives the outer protuberance of the os humeri, and the projecting ridge surrounding this cavity rolls in a small sinus at the upper end of the ulna, in which situation it is held by a ring of cartilage. At the bottom of the radius there is also a similar sinus, which receives the lower end of the ulna. The radius is therefore joined to the ulna by a double

articulation;

articulation; for, above, a tubercle of the radius plays in a socket of the ulna, whilst below, the radius affords the socket and the ulna the tubercle. The motion, however, performed in these two is very different; for, at the upper end, the radius does no more than turn round its axis, while, at the lower end, it moves in a sort of cycloid upon the round part of the ulna; and as the hand is here articulated and firmly connected to the radius, they must move together. The ulna, being connected by a hinge-joint to the os brachii, has scarcely any other motion than that of flexion and extension, in which it carries with it the radius. The motions of the hand, in which the palm is turned either upwards or downwards, are performed by those of the radius on the ulna, carrying with it the hand. From these circumstances it appears, that the ulna more particularly belongs to the os humeri, and the radius to the carpus. The ulna sometimes carries with it the radius, but the radius never moves the ulna, which, like the tibia is connected by a hinge-joint, and has motion only in two directions. The radius is so intimately connected with the hand, and is so much employed in its principal motions, that it has been called *manubrium manus*, or the handle of the hand. Without this peculiar mechanism, the motions of the fore-arm would be as confined as those of the leg; but providence, which has preferred the more firm and secure structure in a part which was destined to support the body, has adapted the fore-arm, by this beautiful and admirable contrivance, for the performance of a number

of motions, with which a hinge-joint would be quite incompatible.

The bones of the hand are divided into those of the carpus, metacarpus, and fingers. The carpus or wrist is formed of eight bones, which are small, of irregular shapes, and distinguished into two series. The form of the carpus is square; that surface, which is contiguous to the palm of the hand, is concave, the opposite is convex. Each of the two series of bones, which compose the carpus, consists of four pieces. The first series, or that which is placed next the bones of the fore-arm, consists of the *os naviculare*, the *os semilunare*, the *os cuneiforme*, and the *os pisiforme*. The bones, which form the other series, are the *os multangulum majus*, the *os multangulum minus*, the *os capitatum*, and the *os cuneiforme*. These bones are covered with cartilage, and are variously articulated with the bones with which they are in contact. The principal use of so great a number of bones in the wrist is to render the hand more flexible. The back part of the hand is convex, for greater firmness and strength; the palm concave, for containing more surely and conveniently such bodies as we take hold of. The upper part of the hand has an obscure motion in comparison with the remainder, and serves as a base to the fingers.

With respect to the metacarpal bones, and those of the fingers, they are so nearly similar to those of the metatarsus and toes, that nothing need be added concerning them.

The reader must undoubtedly have been struck with the great resemblance of structure between
the

the inferior and superior extremities. The os humeri has many points of resemblance to the os femoris, the tibia and fibula to the radius and ulna, and the bones of the carpus, metacarpus, and fingers to those of the tarsus, metatarsus, and toes.

Before the anatomy of the bones, however, is concluded, it will be proper to make a few general remarks on the skeleton of quadrupeds.

In quadrupeds we observe the same general outlines of structure in the osseous system as in man. Their skeletons divide themselves into head, trunk, and extremities; and each of these divisions bears a striking resemblance to the same division in the skeleton of the human body. The cavity of the cranium is much smaller in quadrupeds than in man, in proportion to the other parts, but the bones of the face are much longer; and with respect to this circumstance, as well as many others, the monkey holds a middle place between mankind and quadrupeds.

The spine, as in man, is connected to the cranium; but in quadrupeds this bony column, instead of being placed vertically, is placed horizontally; in both, however, the structure is the same, and the part is subservient to the same purposes. The other parts of the trunk are also very similar to the same parts in man; and the form and relative situation of the sternum and ribs are nearly the same, but the latter are more numerous in quadrupeds. The same resemblance is manifested in the bones of the pelvis, except that the os coccygis is continued beyond the other parts of the body, and forms the tail. The upper part of both

extremities, as in man, is formed of one piece of bone, the lower part of two, and in many quadrupeds there are bones which correspond with the carpus and tarsus, the fingers and the toes. The clavicula or collar-bone is in general, however, wanting in quadrupeds, and is only found in monkeys, squirrels, and some other animals, which are skilful in climbing, and which employ their fore legs for other purposes than that of travelling. In short, the skeleton of the quadruped is so similar to that of man, that when the skeleton of the former is placed erect on the hind-legs, it may easily, by persons unacquainted with anatomy, be mistaken for that of the latter.

The figure in Plate II. represents a front view of the human skeleton, with some of the ligaments and cartilages, which connect the bones to each other.

HEAD and NECK.

a, Os frontis.

b, Os parietale.

Between *a* and *b*, part of the coronal suture.

c, The pars squamosa of the temporal bone.

Between *b* and *c*, the squamous suture.

Below the pars squamosa, the zygoma; and, lower down, above *f*, the mastoid process.

Between the pars squamosa and the cavity, which contains the eye-ball, called the *orbit*, the temporal process of the sphenoid bone is seen.

d, Os malæ.

Above *d*, a portion of the transverse suture.

e, Os maxillare superius, with the eight teeth of the right side.

The

The nasal process of the superior maxillary bone has the os nasi joined, by the lateral nasal suture, to its inside; and at the outside, within the orbit, the os unguis.

The ossa nasi joined to each other before, by the anterior nasal suture.

f, Os maxillare inferius with sixteen teeth; the four anterior named *incisores*, the two corner ones *canini*, and the five posterior on each side *molares*.

Opposite to *f*, the angle of the lower jaw; above *f*, the condyloid process, by which the jaw is connected to the temporal bone, at the root of the zygoma; and behind the os malæ, the coronoid process.

g, The seven cervical vertebræ, with their intermediate cartilages.

Opposite to *g*, their transverse processes.

T R U N K.

a, Sternum.

a, its middle piece, to which one half of the cartilage that connects the second rib, the whole of the cartilages of the third, fourth, fifth, sixth, and one half of the seventh, are fixed.

Above *a*, the first or upper triangular piece, to which the clavicle and one half of the cartilage that connects the second rib are fixed.

Below *a*, the extremity, or third piece of the sternum, named the *cartilago ensiformis*, to which one half of the cartilage that connects the seventh rib is fixed.

b, The seventh, or last true rib.

c, The twelfth, or last of the five false ribs.

d, The five lumbar vertebræ, with their intermediate cartilages.

Opposite to *d*, their transverse processes.

e, The os sacrum, with its five divisions,

f, Os innominatum, divided into

g, Os ilium,

h, Os pubis,

i, Os ischium.

Opposite to *i*, the foramen thyroideum.

SUPERIOR EXTREMITY.

a, The clavicle fixed before, to the first piece of the sternum, and outwards to the acromion of the scapula.

b, The scapula.

Above *b*, the cervix of the scapula.

Opposite to it, the inferior costa; and below the outward extremity of the clavicle, the superior costa, and coracoid process, are seen.

c, the os humeri.

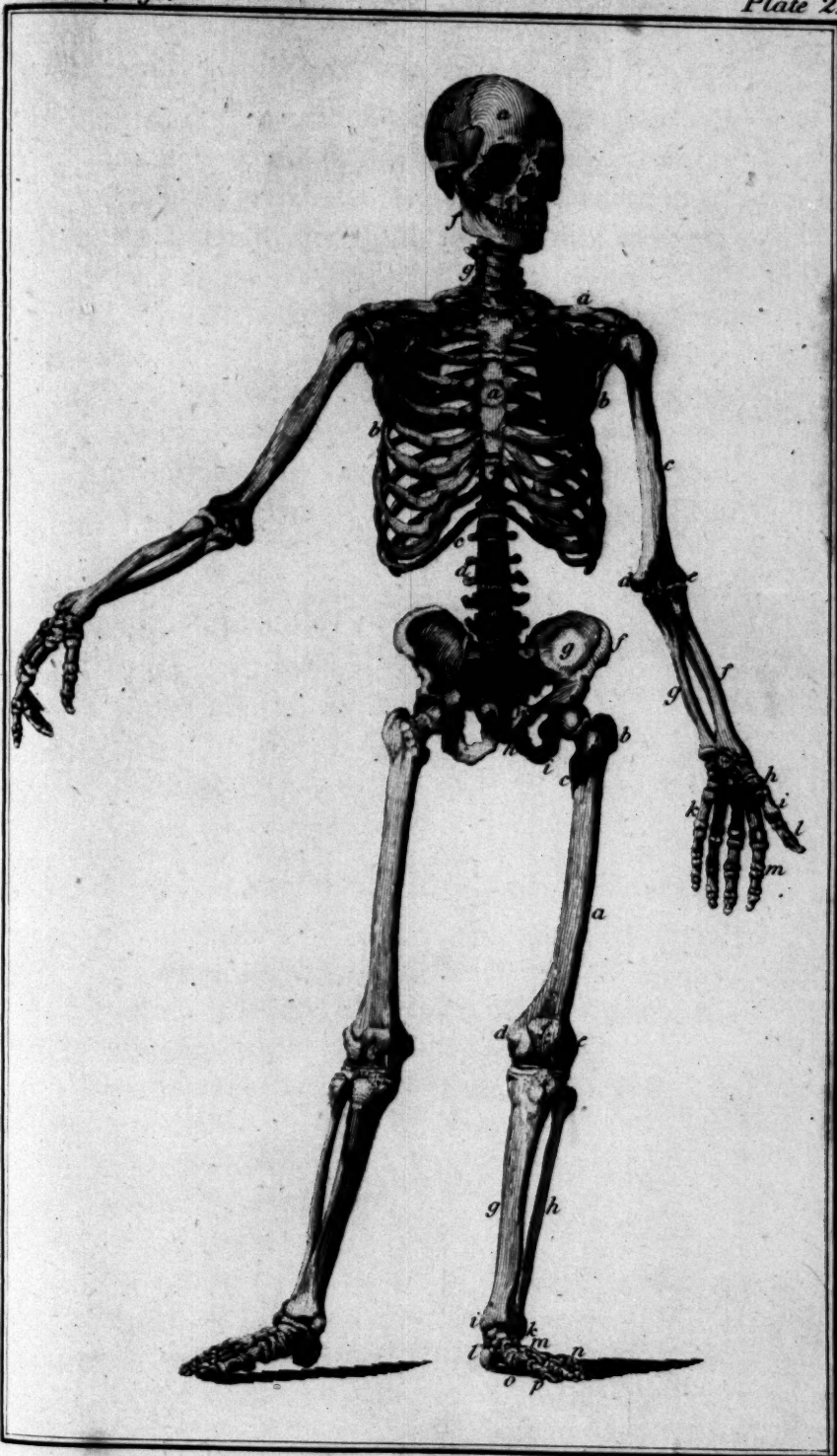
The upper end of it, which is connected to the cavity of the scapula, named the *glenoid*, below the acromion, is named its *head* or *ball*; on each side of which is seen the tubercles, named the *external* and *internal*; and between these, a groove for lodging the long head of the biceps flexor cubiti.

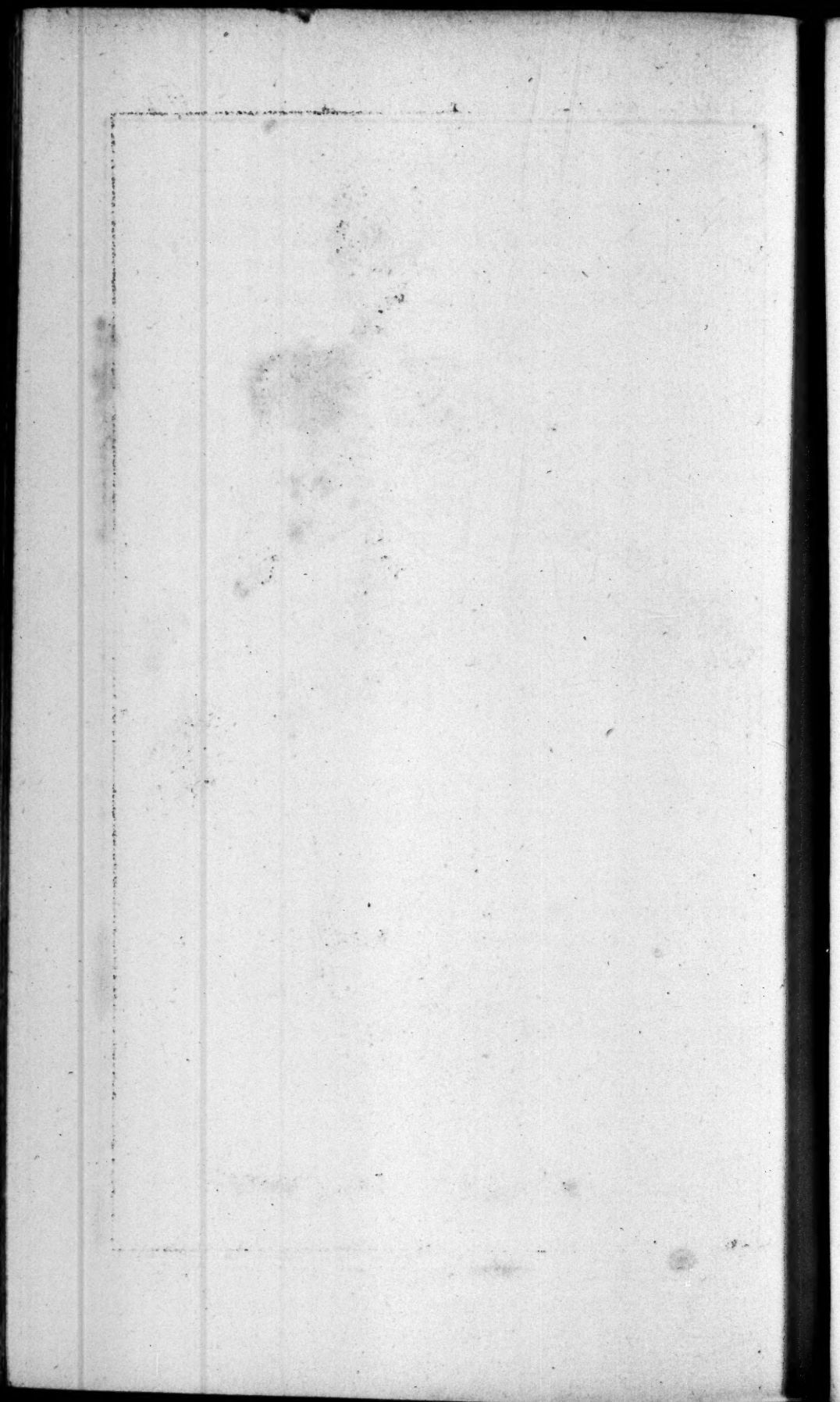
d, The internal condyle.

e, The external condyle.

Between *d* and *e*, the trochlea, upon which the ulna moves.

f, The radius.





The upper end, which moves on the external condyle of the os humeri, is named its *head*; below that, the tubercle for the insertion of the biceps flexor cubiti, and between these the cervix.

The inferior end of it is connected to the carpus.

g, Ulna.

The upper end of it forms the coronoid process, for the insertion of the brachialis muscle.

The inferior end has a process named the *styloid*, which is connected to the carpus by a ligament.

b, The carpus, formed of eight bones.

i, Metacarpal bone of the thumb.

k, The metacarpal bones of the four fingers.

l, The two joints of the thumb.

m, The three joints or phalanges of the fore-finger; and the same are seen in each of the other three.

INFERIOR EXTREMITY.

a, Os femoris.

The upper end of it is named its *head* or ball, which is lodged in a deep socket of the os innominatum, named the *acetabulum*.

Between the head and trochanter major, the cervix.

b, Trochanter major.

c, Trochanter minor.

d, Internal condyle.

e, External condyle.

f, Patella.

The place where it moves upon the os femoris, is named the *trochlea*.

g, Tibia.

Between

Between the tibia and the condyles of the os femoris, the femilunar cartilages are seen; and below the joint, the tubercle of the tibia.

b, Fibula.

i, Malleolus internus.

k, Malleolus externus.

l, Os calcis.

Between *l* and *m*, the other six bones of the tarsus,

m, Metatarsal bones of the four toes.

n, The three joints, or phalanges, of the four toes.

o, Metatarsal bone of the great toe.

p, The two joints of the great toe.

The figure in plate III. represents a back view of the human skeleton, with some of the ligaments and cartilages which connect the bones.

HEAD and NECK.

a, Os parietale, joined to its fellow by the sagittal suture.

b, The os occipitis, joined to the parietal bones by the lambdoid suture, which is between *a* and *b*.

c, Os malæ.

d, Maxilla inferior, with a view of the teeth of both jaws from behind.

e, The seven cervical vertibræ.

TRUNK.

a. The seventh or last true rib.

b, The twelfth or last rib.

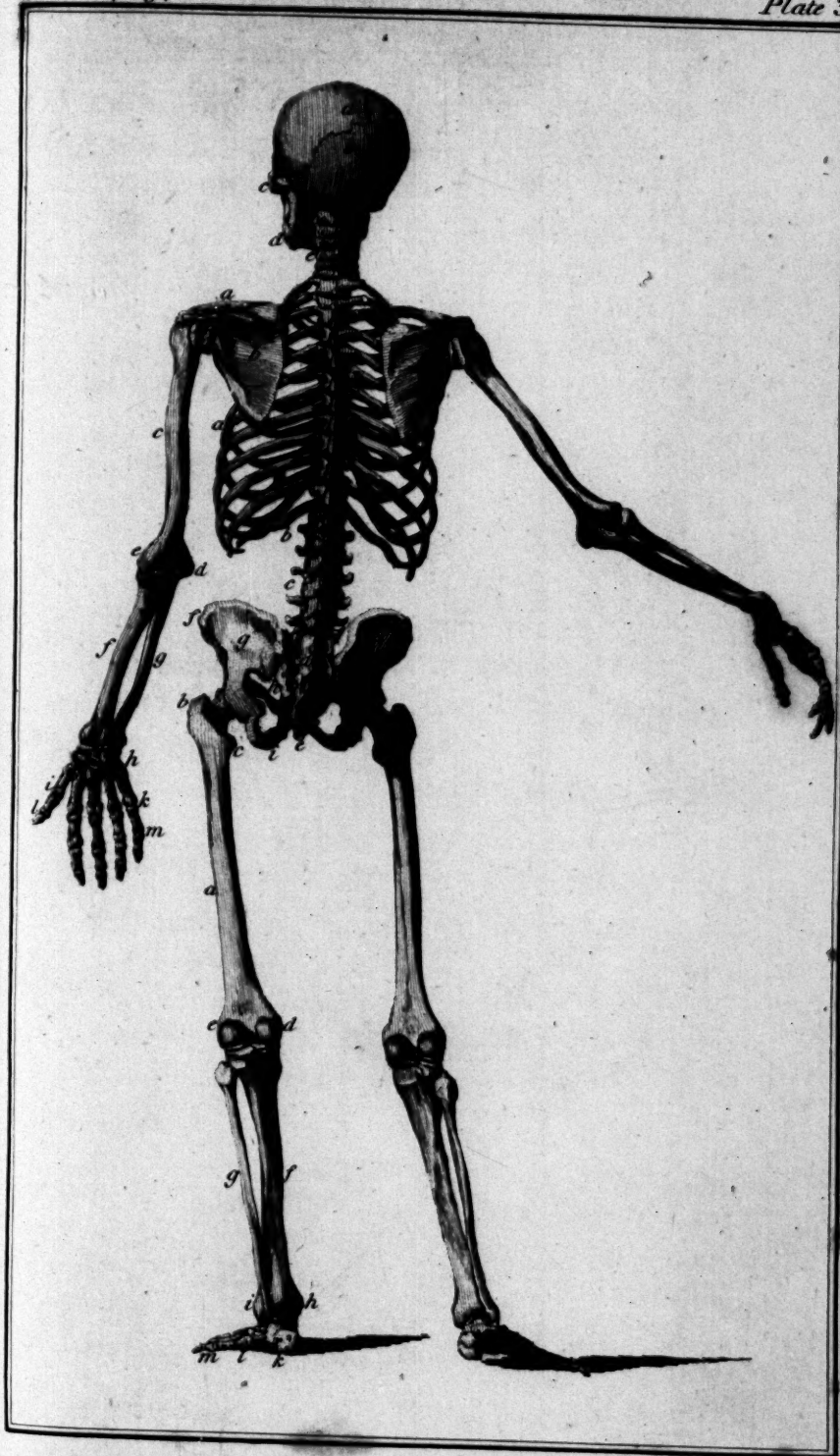
c, The five lumbar vertebræ,

d, Os sacrum.

e, Os coccygis.

f, Os innominatum, divided into

g, Os



- g*, Os ilium.
- b*, Os pubis.
- i*, Os ischium.

SUPERIOR EXTREMITY.

- a*, The clavicle, joined outwards to the acromion of the scapula.
- b*, The scapula.
- c*, Os humeri.
- d*, Internal condyle.
- e*, External condyle.
- f*, Radius.
- g*, Ulna, its upper end, named *olecranon*; and near the wrist, its styloid process.
- h*, The eight bones of the carpus.
- i*, The metatarsal bone of the thumb.
- k*, The metatarsal bones of the four fingers.
- l*, The two joints of the thumb.
- m*, The three joints or phalanges of the four fingers.

INFERIOR EXTREMITY.

- a*, Os femoris.
- b*, Trochanter major, and at the inside of it the cervix.
- c*, Trochanter minor.
- d*, Internal condyle.
- e*, External condyle.
- f*, Tibia.
- g*, Fibula.
- h*, Malleolus internus.
- i*, Malleolus externus.
- k*, The seven bones of the tarsus.
- l*, The metatarsus.
- m*, The joints or phalanges of the toes.

C H A P. X.

STRUCTURE OF THE MUSCLES.

General Description of Muscles.—Observations of the Abbè Fontana.—Of Leeuwenhoek.—Muscles composed of small Fibres.—Structure of different Muscles.—Antagonists.—Muscles of the Fœtus.

THE bones, considered with relation to the motions of the body, are merely levers; let us now consider the structure of the muscles, which are the immediate sources of all the motions of the animal machine.

The animal substance, which the anatomist calls muscle, is that which in common language passes under the name of the lean or flesh of meat. The colour of the muscles, when they are first removed from the body, is red; this colour, however, is not essential to them, but is merely owing to the presence of blood, for when muscle is cleansed from blood, it appears white. In every recent muscle we may at first view distinguish two kinds of fibres; the one kind appears red, and is the true muscular substance; the other is tendinous, has a white silvery appearance, and has no power of contraction like the former. The tendinous substance is sometimes collected into a cord, but is very frequently expanded, so as by covering the surface of a muscle, or by pervading its substance, to afford a very extensive connexion to muscular fibres.

The

The Abbè Fontana has taken great pains to examine the structure of muscles. He divided muscular substance with the point of a small needle till he came to minute threads, which, whatever pains he took, would admit of no further division. These, he examined with a lens, the diameter of which was one-ninth of an inch; when they appeared to be solid homogeneous cylinders, interrupted at regular distances by very minute lines or wrinkles. These wrinkles, when they were examined in different points of view, might have passed for globules; but upon this circumstance, as the observation went no further, the Abbè does not insist. This undulated appearance has also been observed in nervous and tendinous fibres, examined by microscopes of high magnifying powers. Dr. Monro, in his observations on the nervous system, gives it as his opinion, that they are to be considered as folds or joints, serving to accommodate the parts to the different states of flexion and extension. In proof of this he finds, that those parts which have this appearance in their relaxed state, lose it when stretched.

Leuenhoeck long ago fancied that he had discovered the ultimate muscular fibre, which he considered as being one hundred times as small as a hair. He afterwards, however, candidly acknowledged, that what he supposed to be a simple fibre was, in fact, a bundle of them. Notwithstanding, therefore, the microscopical observations of the Abbè Fontana, and other philosophers, we must still acknowledge ourselves ignorant of the structure of the ultimate component parts of muscular substance; and all we are allowed to say is, that their structure is fibrous.

These minute fibres, observed by the Abbè Fontana, were tied by cellular substance in small fasciculi or bundles, these bundles are again formed into larger by the same means, and of these fasciculi are composed those contractile masses of flesh called muscles.

Muscles are generally connected at their two extremities to bones, by means of tendons; the largest part of a muscle is called its belly, and is chiefly composed of contractile muscular fibres. That connection of a muscle which is least moveable is called its origin, that which is most moveable its insertion; but these terms are in many cases merely relative, for a part of the body which is more fixed in one posture becomes less so in another. The fibres which compose a muscle run either longitudinally, transversely, obliquely, or circularly. If all the fibres which compose a muscle run in the same direction, it is called rectilinear; radiated, if the fibres are disposed like radii; penniform, if, resembling the plume of a feather, the fibres are situated obliquely with respect to the centre from which they proceed; compound, if the fibres run in different directions. The majority of the large muscles of the body are compound.

Most muscles have others opposed to them, which act in a contrary direction, and are called antagonists. Thus, one muscle, or one set of muscles, bends a limb, another extends it; one elevates a part, another depresses it; one draws it to the right, another to the left. By these opposite powers the part is kept in a middle direction, ready to be drawn either one way or another, as particular muscles are thrown

thrown into stronger action. The flexor muscles exceed the extensors in strength, and for this reason the easiest postures are those in which the body or limbs are moderately bent.

When we speak of the muscles of a part, we do not mean those which are situated on it, but those which serve to move it. Thus, what are called the muscles of the leg, and which are subservient to its motions, are placed round the thigh bone; those which move the foot, round the bones of the leg, &c.

In the foetus the muscles are evidently inserted into the periosteum only, but in the adult state, when the periosteum adheres much more closely to the bone, the tendons, being confused with the periosteum, pass with that even into the foveoli of the bone.

CHAP. XI.

MUSCLES OF THE HEAD.

Muscles of the Forehead.—Of the Eye-lids.—Of the Eye.—Of the Nose.—Muscles of the Mouth.—Why the Face is the Index to the Mind.—Temporal Muscles.—Muscles of the Neck.—Of the Jaw.—The Tongue.—Muscles of the Palate, &c.

THE skin which covers the head is moved by a single broad muscle, and one small pair. The former of these is situated immediately below the common integuments, at the back and fore part of the head, with the intervention of a broad tendon, and is called occipito frontalis. Its effect is to draw the skin of the head backwards, to raise the eye-brows, and wrinkle the skin of the forehead.

The corrugator supercilii arises from the internal angular process of the os frontis, near its joining with the bones of the face; it is inserted into the inferior and inner part of the occipito frontalis, draws the eye-brows towards each, pulls downwards the skin of the forehead, and causes it to wrinkle, particularly between the eye-brows.

The muscles of the ear will be spoken of when it becomes necessary to treat of the organs of hearing.

The muscles of the eye-lids are, the orbicularis palpebrarum, which surrounds the eye, and has the effect of shutting the eye-lids. The upper eye-lid has also a muscle proper to itself, called the levator palpebræ superioris, the effect of which is to raise the
upper

upper eye, and consequently to counteract the former.

The ball of the eye has six muscles, four strait and two oblique. The strait muscles all rise from the bottom of the orbit around the foramen, through which the optic nerve passes, and are extended to the fore part of the globe of the eye. These muscles are named from their use. The levator oculi raises the ball of the eye, the depressor pulls it down, the adductor turns the eye towards the nose, and the abductor moves the globe outwards. The two oblique muscles are, the obliquus superior or trochlearis, which, rising from the bottom of the orbit, runs along the pars plana of the ethmoid bone to the upper part of the orbit, where its tendon passes through a cartilaginous ring connected to the os frontis, by which mechanism the direction of its force is altered, and its tendon afterwards proceeding a little downwards, and directed outwards at the same time, is inserted half way between the insertion of the attollens oculi and optic nerve. The effect of this curious muscle is to roll the eye, to turn the pupil downwards and outwards, and to draw the whole ball nearer to the nose. The obliquus inferior arises from the orbital process of the superior maxillary bone, and running obliquely outwards is inserted in the space between the abductor and optic nerve. Its use is to draw the globe of the eye forwards, inwards, and downwards, and, contrary to the superior oblique, to turn the pupil upwards towards the inner extremity of the eyebrow. By acting successively with all the muscles of the eyes we are able to roll them.

The nose is affected by several muscles of the face, but only one pair is commonly considered as properly belonging to it. This, which is called the *compressor naris*, arises externally from the root of the *alæ nasi*, and running obliquely upwards along the cartilage of the nose, joins its fellow, and is inserted into the neighbouring bone. The effect of this muscle is to compress the *alæ* towards the *septum naris*, particularly when we want to smell acutely; it also wrinkles the skin of the nose.

The mouth has nine pair of muscles inserted into the lips, where their terminations form a single muscle, which surrounds the mouth. One of these rises from the upper jaw-bone, and is inserted into the angle of the mouth. Its effect is to raise the corners of the mouth, and it is therefore called the *levator anguli oris*.

2. The *levator labii superioris alæque nasi*. This rises by two distinct origins; one of these proceeds from the superior maxillary bone immediately below the orbit, the other from the same bone at the inner angle of the eye. It is inserted partly into the upper lip and partly into the outer part of the *alæ nasi*, raises the upper lip towards the eyes and a little outwards, and also dilates the nostrils, by drawing the *alæ nasi* upwards and outwards.

3. The *depressor labii superioris alæque nasi*, arises from the upper jaw-bone, where the *dentes incisivi* and *canini* are fixed, and is inserted into the upper lip and root of the *alæ nasi*. When it acts, it draws the upper lip and *alæ nasi* downwards and backwards.

The

The three muscles of the mouth, already mentioned, are situated above, the three other pairs are placed below:

4. The depressor anguli oris arises from the lower edge of the maxilla inferior, and is also connected to the neighbouring soft parts: It is inserted into the corners of the mouth, and pulls them downwards.

5. The depressor labii inferioris arises from the inferior part of the lower jaw-bone, near the chin, is inserted into the edge of the lower lip, and pulls it downwards and a little outwards. 6. The levator labii inferioris arises from the lower jaw, where the dentes incisivi and canini are fixed, and, being inserted into the under lip and skin of the chin, draws them upwards:

Three pair of muscles are also seated outwards with respect to the mouth.

7. The buccinator (or trumpeter) arises from both jaws, adheres closely to the membrane of the mouth, and is inserted at its angles. Its effect is to draw the angles of the mouth backwards and outwards, and to contract its cavity, as in blowing a wind instrument; and in pushing our meat between the teeth. 8. The zygomaticus major arises from the os malæ, near the zygomatic future, and is inserted into the angle of the mouth. When it contracts, it draws the angles of the mouth upwards and outwards, and makes the cheeks prominent as in laughing. 9. The zygomaticus minor descends obliquely from the prominent part of the os malæ, and is inserted into the upper lip near the corner of the mouth. Its use is to draw the corner of the mouth obliquely upwards and outwards towards the external corner of the eye.

The single muscle, which was mentioned as being formed by the terminations of all the others decussating each other, is called the orbicularis oris, and entirely surrounds the mouth. Its use is to shut the mouth, by contracting and drawing both lips together, and to counteract all the muscles which contribute to its formation.

The muscles of the face are the organs, which, being affected by the passions, render the human countenance an index of what is passing in the mind; and, as all muscles acquire a greater degree of strength as well as proneness to action in proportion to the degree in which they are employed, so the countenance becomes impressed with a general character, which is the foundation of physiognomy. For this reason the countenances of old people are more expressive, and their likenesses more easily taken, than those of the young, though this is partly to be attributed to the wasting of the fat, which in youth fills the interstices between the muscles, and prevents strong lines. To the above principle is to be attributed the greater expression observable in the countenance of a person of a cultivated mind than in that of a person whose stock of ideas is narrow. From all these circumstances it appears, that the cultivation of the mind is the most likely method of increasing the expression and beauty of the countenance.

The muscles of the lower jaw are four pairs, and are those employed in the mastication of the food.

The temporalis muscle has a very extensive origin, from the lower and lateral part of the parietal bone, all the pars squamosa of the temporal bone,
from

from the external angular process of the os frontis, and from the temporal process of the sphenoid bone. From these different origins the fibres descend like radii towards the jugum, under which they pass, and are inserted into the coronoid process of the lower jaw. Its use is to press the lower jaw against the upper, and at the same time to draw it a little backwards. This muscle is covered with a broad tendon, called its aponeurosis, which defends it, and gives origin to a great number of muscular fibres.

The masseter arises from the superior maxillary bone, where it joins the os malæ, and from the inferior and anterior part of the jugum, and is inserted into the angle of the lower jaw, which, when it acts, it presses against the upper.

The pterygoideus internus proceeds from the inner and upper part of the internal plate of the pterygoid process of the sphenoid bone, and from the pterygoid process of the os palati. It is inserted into the angle of the lower jaw internally, and, when it acts, draws it upwards and obliquely towards the opposite side.

The pterygoideus externus takes its origin from the outer side of the pterygoid process of the sphenoid bone, from part of the tuberosity of the os maxillare adjoining to it, and from the root of the temporal process of the sphenoid bone. It is inserted into the neck of the condyloid process of the lower jaw, and pulls it forwards and to the opposite side, or when both the external pterygoid muscles act, the fore teeth of the under jaw are pushed forwards beyond those of the upper jaw.

On the side of the neck, towards its fore part, are two muscles. The external of these is a muscle of the skin, and is called *platysma myoides*. It arises by a number of slender fibres from the cellular substance, which covers the upper parts of the deltoid and pectoral muscles; in their ascent they all unite to form a thin muscle, adhering to the skin, and which is inserted into the lower jaw. It draws the skin of the cheek downwards.

The *sterno-cleido-mastoideus* has two origins, one from the sternum, the other from the clavicle, which, uniting, form one muscle, which runs obliquely upwards and outwards, and is inserted into the mastoid process of the temporal bone. When it contracts, it turns the head to one side, and bends it forwards; or when its fellow acts with it, they draw the head directly forwards.

Six pairs of muscles are situated between the *os hyoides* and the lower jaw.

The muscle, which forms the external layer, is called the *digastricus*. It rises near the mastoid process, runs downwards and forwards to the *os hyoides*, and thence proceeds to the bone of the chin, into which it is inserted. When it acts, it pulls the lower jaw downwards and backwards, and therefore opens the mouth. When the lower jaw, however, is fixed by the stronger muscles, which have been already described, the effect of the *digastricus* is different, for the *os hyoides*, then becoming the more moveable part, is drawn upwards, and with it the larynx and pharynx, as in the act of swallowing.

The *mylo-hyoideus* passes from the inside of the

lower jaw to the os hyoides, and has nearly the same effect as the digastricus.

The genio-hyoideus also passes from the os hyoides to the chin, and either raises the former or pulls down the latter, according as the lower jaw or the os hyoides is rendered more fixed by other muscles.

The genio-hyo-glossus arises from the lower jaw, and is inserted partly into the os hyoides, and partly into the tongue. This muscle, according to the direction of its fibres, acts very differently on different occasions; from the separate action of its fibres it either draws the tongue backwards, extends it out of the mouth, or renders its upper part concave.

Two muscles pass from the os hyoides to the trunk. The sterno hyoideus proceeds from the sternum, and pulls the os hyoides downwards. The omo hyoideus arises from the superior costa of the scapula, and draws the os hyoides obliquely downwards. It is to be noticed, that when there are two muscles of equal strength and equal obliquity attached to a moveable part, and they both act together, they draw it in a strait line, the obliquity of the one counterbalancing that of the other.

The substance of the tongue is muscular, and is distinguished by anatomists into six pair of muscles, which it cannot be necessary to enumerate. They also describe six pair of muscles belonging to the pharynx; these I shall pass over in silence, and merely consider it as a muscular bag, forming the upper part of the alimentary canal. There

are also several muscles belonging to the palate and uvula, of which the limits of this work do not permit the specification. I shall at present also pass over the muscles of the larynx, as a better opportunity will occur of comprehending them under the description of the parts to which they belong. The same observation is applicable to the muscles of the ear.

C H A P. XII.

MUSCLES OF THE TRUNK.

*Muscles of the Neck and Back.—Of the Breast.—Of the Ribs.—
The Diaphragm.—Muscles of the Abdomen.—Of the Pelvis, &c.*

ON the anterior part of the neck, close to the vertebræ, are seated the following muscles :

The longus colli arises from the bodies of three of the vertebræ of the back, and from the transverse processes of most of the vertebræ of the neck. It is inserted into the fore part of all the vertebræ of the neck, and has the effect of drawing it forwards or to one side, according as the muscle on both sides, or that on one only, is called into action.

The rectus capitis internus major proceeds from the extremity of the transverse processes of the three, four, five, and six vertebræ of the neck, is inserted into the cuneiform process of the os occipitis, and bends the head forwards.

The rectus capitis internus minor arises from the fore part of the body of the first vertebra of the neck, is inserted into the condyloid process of the os occipitis, and also bends the head forwards.

The rectus capitis lateralis arises from the anterior part of the point of the first transverse process of the first vertebra of the neck, and is inserted into the os occipitis, and bends the head a little to one side.

The

The large and strong muscles, seated at the posterior part of the trunk, may be divided into four layers and a single pair. The external layer consists of two very broad muscles.

The trapezius arises by a strong round tendon, from the middle of the os occipitis, and from a rough curved line, which extends thence towards the mastoid process of the temporal bone. It proceeds downwards along the nape of the neck, is attached to the spinous processes of all the vertebræ of the back, and the two lowest of the neck, and is also firmly connected by the intervention of a tendon to its fellow of the opposite side. It is inserted into the posterior part of the clavicle, the acromion, and almost all the spine of the scapula. It moves the scapula either obliquely upwards, directly backwards, or obliquely downwards, according as its different parts are called into action.

The latissimus dorsi arises, by a broad thin tendon, from the posterior part of the spine of the os ileum, from the spinous processes of the os sacrum, loins, and seven inferior of the back, and from three or four of the lower ribs; its fibres converging pass over the inferior angle of the scapula, are collected into a flat cord in the axilla, and inserted into the os humeri. Its action is to pull the arm downwards and backwards, and to roll the os humeri.

The second layer of muscles consists of three pair, two on the back and one on the neck. On the back are seated the serratus posticus inferior. This muscle originates from the spinous processes of the two inferior of the back and three superior vertebræ of the loins, is inserted into the four lowest ribs,

ribs, which it draws downwards, and is therefore a muscle of expiration.

The rhomboideus proceeds from the spinous processes of the five superior vertebræ of the back and three inferior of the neck, and is inserted into the base of the scapula, which it draws obliquely upwards, and directly inwards towards the spine.

On the neck is situated,

The splenius, which arises from the spinous processes of the four upper vertebræ of the back and five lower of the neck; it is inserted into the transverse processes of the five superior vertebræ of the neck, the posterior part of the mastoid process, and the os occipitis, where it joins the root of that process. When one of these muscles acts, it brings the head and neck obliquely backwards, or, when they both act, they draw the head directly backwards.

The single pair, which was mentioned, is the

Serratus posticus superior. This originates from the spinous processes of the three lowest vertebræ of the neck, and two uppermost of the back, and is inserted into the second, third, fourth, and fifth ribs. Its effect is to elevate the ribs, dilate the thorax, and consequently it is subservient to inspiration.

Having removed these muscles, we come to the third layer, which consists of three on the back, and three on the neck.

On the back are,

The spinalis dorsi, which arises from the spinous processes of the two uppermost vertebræ of the loins and three inferior of the back, and passes to the nine uppermost spinous processes of the vertebræ

tebræ of the back. The evident effect of this muscle is to straiten the spine, and prevent it from bending forwards.

The longissimus dorsi originates from the side of the os sacrum, and its spinous processes; from the posterior spine of the ileum; from all the spinous processes, and from the roots of the transverse processes of the vertebræ of the loins. It is inserted into all the transverse processes of the vertebræ of the back, and also into the lower edge of the ten uppermost ribs, near their tubercles. This muscle strengthens the spine, and keeps the body from bending forwards.

The sacro-lumbalis, which arises in common with the longissimus dorsi, is inserted into all the ribs near their angle. It pulls down the ribs, and assists in erecting the trunk of the body.

On the neck we find, the

Complexus, which arises from the transverse processes of the seven superior vertebræ of the back and four inferior of the neck; it is inserted, with the trapezius, into the inferior edge of the protuberance in the middle of the os occipitis, and into a part of the curved line which runs towards the mastoid process. When they both act, they draw the head directly backwards, or obliquely so when only one is called into action.

The trachelo-mastoideus, which arises from the transverse processes of the three uppermost vertebræ of the back, and from the five lowermost of the neck, where it is connected to the transversus cervicis, is inserted into the posterior part of the mastoid process.

cess. It assists the complexus, but pulls the head more to one side.

The levator scapulæ arises from the transverse processes of the five superior vertebræ of the neck, and is inserted into the superior angle of the scapula. It elevates the scapula, and draws it a little forwards.

The fourth layer consists of two pair on the back, two on the posterior part of the neck, four small pair, situated immediately below the posterior part of the occiput, and three on the side of the neck.

On the back are the

Semispinalis dorfi, which arises from the transverse processes of the seventh, eighth, ninth, and tenth vertebræ of the back, is inserted into the spinous processes of all the vertebræ of the back above the eighth, and into the two lowermost of the neck. Its effect is to extend the spine backwards.

The multifidus spinæ originates from the side and spinous processes of the os sacrum, and from the posterior part of the os ilicum, where it joins the sacrum; from all the oblique and transverse processes of the vertebræ of the loins; from all the transverse processes of the vertebræ of the back, and from those of the neck, except the three upper; its tendinous and muscular fibres run in an oblique direction, and are inserted into the spinous processes of all the vertebræ of the loins, of the back, and of the neck, except the first. When one side of this muscle acts by itself it extends the spine obliquely, when both act they draw it directly backwards.

On

On the posterior part of the neck are the *semispinalis colli*, which arises from the transverse processes of the six uppermost vertebræ of the back, and is inserted into the spinous processes of all the vertebræ of the neck. It extends the neck backwards.

The *transversalis colli*, which proceeds from the transverse processes of the five uppermost vertebræ of the back, and is inserted into the transverse processes of all the cervical vertebræ, except the first and the last. It turns the neck obliquely backwards and a little to one side.

Below the posterior part of the occiput are,

The *rectus capitis posterior major*. This muscle arises from the external part of the spinous process of the second vertebra of the neck, ascends obliquely outwards, and is inserted into the *os occipitis*. It pulls the head backwards, and assists a little in its rotation.

The *rectus capitis posterior minor* arises from a little protuberance in the middle of the back part of the first vertebra of the neck, and is inserted near the foramen magnum of the *os occipitis*. It assists in moving the head backwards.

The *obliquus capitis superior* arises from the transverse process of the first vertebra of the neck, and is inserted into the *os occipitis*. It draws the head backwards.

The *obliquus capitis inferior* arises from the spinous process of the second vertebra of the neck, and is inserted into the transverse process of the first vertebra of the neck. This muscle acts very powerfully in giving a rotatory motion to the head.

On

On the side of the neck are the scalenus anticus, which arises from the fourth, fifth, and sixth transverse processes of the vertebræ of the neck, and is inserted into the upper part of the first rib.

The scalenus medius, which proceeds from all the transverse processes of the vertebræ of the neck, and is inserted into the upper and outer part of the first rib.

The scalenus posticus, which arises from the fifth and sixth transverse processes of the vertebræ of the neck, and is inserted into the upper part of the second rib.

The effect of all the scaleni is to bend the neck to one side, or, when the neck is fixed, to raise the ribs and dilate the thorax.

There are a number of small muscles situated between the spinous and transverse processes of contiguous vertebræ, some of which approach so nearly to the nature of tendons as to serve merely as ligaments. The use of all these is to strengthen and erect the spine.

In the description which has been given of the muscles which serve for the motion of the whole head, the reader cannot have failed to observe, how much more numerous those are which are inserted into the back part of the head, and pull it backwards, than those which have the opposite insertion and effect. The reason of this is, that the center of gravity of the head does not fall on the condyls, on which it is supported, but considerably farther forward; from which mechanism it is evident that the muscles which pull the head back must be continually acted against. Hence, when a person falls asleep,

asleep, or is affected with the palsy, and the muscles cease to act, the head always falls forwards. By the spine being thus connected towards the posterior part of the cranium, more space is allowed for the cavities of the mouth and fauces.

Muscles situated on the anterior part of the thorax.

After having removed the common integuments of the thorax, we observe a large muscle, the *pectoralis major*, which rises from the cartilaginous extremities of the fifth and sixth ribs, from almost the whole length of the sternum, and from near half the anterior part of the clavicle. Its fibres run towards the axilla, and it is inserted into the upper and inner part of the *os humeri*. Its effect is to move the arm forwards and obliquely upwards towards the sternum.

Having removed this we come to another layer, which consists of three muscles.

The *subclavius* is a small muscle which rises from the first rib, and is inserted into the inferior part of the clavicle. Its effect is to pull the clavicle downwards and forwards.

The *pectoralis minor* arises from the upper edge of the third, fourth, and fifth ribs, and is inserted into the coracoid process of the scapula. Its use is to bring the scapula downwards and forwards, or that being fixed, to pull the ribs upwards.

The *serratus magnus* originates from the nine superior ribs, by an equal number of fleshy digitations, resembling the teeth of a saw, whence the term *serratus* is derived. Being folded about two angles of the scapula it is inserted into its base. Its effect is to move the scapula forwards, or when
the

the scapula is forcibly raised, to draw the ribs upwards.

The muscles which cover the ribs being removed, we observe the space between the ribs filled up with double rows of muscles, called the *intercostales externi* and *interni*. The external arise from the inferior acute edge of each rib, and running obliquely forwards are inserted into the obtuse upper surface of the rib next below. The internal arise in the same manner as the external, except that, contrary to them, they begin at the sternum, and run obliquely backwards. The two rows of intercostals, therefore, decussate each other like the strokes of the letter X. The effect of the contraction of both series is the same, viz. that of bringing the ribs nearer to each other, and as each lower rib is more moveable than that above, to raise the ribs, dilate the thorax, and assist in inspiration.

Certain portions, both of the external and internal intercostals, are longer, and passing over one rib are inserted into the next below it. The ribs are likewise raised, and their posterior articulations strengthened, by twelve short muscles, which arise from eleven of the transverse processes of the dorsal vertebræ, and the lowest of those of the neck, and which are inserted into the rib immediately below the transverse process from which each of them rises.

The *sterno-costalis* arises from the *cartilago ensiformis*, and is inserted into the lower edge of the cartilages of the third, fourth, and fifth ribs. Its effect is to depress these cartilages and the extre-

mities of the ribs, to contract the cavity of the thorax, and therefore to assist in expiration.

The most important muscle of the thorax, however, still remains to be considered. The diaphragm is a broad and strong muscle, which divides the cavity of the abdomen from that of the thorax. It is placed very obliquely between these two cavities, its anterior connection being much higher than its posterior. Its middle part is forced up by the viscera of the abdomen, so as to form an arch. The diaphragm, at its anterior part, arises from the upper and internal part of the ensiform cartilage, and from the cartilages of the sixth, seventh, and all the inferior ribs. The muscular portions arising from all these points converge towards a common center, where they terminate in a broad triangular tendon. This being directed downwards and backwards is attached to a muscular substance, which arises by eight heads from the second, third, and fourth lumbar vertebræ. There are several passages through the diaphragm, which must not be passed over in silence. Among the muscular portions which proceed from the lumbar vertebræ are openings through which pass the aorta, the thoracic duct, the vena azygos, and the two great intercostal nerves. The muscular fibres, which proceed from the lumbar vertebræ, run obliquely upwards and forwards, and form in the middle two fleshy columns, which decussate, and leave an oval space between them for the passage of the œsophagus and eighth pair of nerves. Towards the right side of the broad tendon, which forms the middle of the diaphragm, there is a large

quadrangular opening, through which the vena cava passes to arrive at the heart. When the diaphragm contracts, its concavity is lessened, particularly on each side, over which the lungs are placed, its center being firmly fixed from its connection with the mediastinum. By the descent, however, of its sides, it pushes downwards and forwards the abdominal viscera, it lengthens, and of course enlarges, the cavity of the thorax, and is the principal muscle of inspiration. The ribs are at the same time raised by the intercostal muscles, by which the thorax is made wider. The chief muscles of expiration, on the other hand, are those which surround the abdomen. These counteract the intercostals, by pulling down the ribs, in which they are assisted by the serrati, and oppose the diaphragm by the postici inferiores pressing backwards and upwards the abdominal viscera. By these muscles respiration is in general carried on. In cases, however, of laborious respiration, whether from disease or violent exercise, other muscles are called into action; inspiration is then promoted by the pectoral muscles, the serrati antici majores, the serrati postici posteriores, and the scaleni. That these muscles may act with more advantage, persons labouring under difficult respiration extend and fix the neck, and raise the shoulders. In laborious expiration the quadrati lumborum, sacro-lumbales, and longissimi dorsi, concur in pulling down the ribs. The elasticity of the cartilages of the ribs is also on all occasions an agent in expiration.

The muscles situated on the anterior part of the abdomen are five pair. On the middle of the an-

terior part of the abdomen, three of its muscles, the two oblique and the transverse, terminate in tendinous substance, which forms an expansion the whole way from the cartilago ensiformis to the ossa pubis. This from its white appearance is called *linea alba*. The external layer is formed by a muscle, which from its situation and the direction of its fibres is called the *obliquus descendens externus*. This muscle rises by as many heads from eight or nine of the lowest ribs; its notches always mix with those of the *serratus major anticus*, and generally cohere to the *pectoralis major*, *intercostals*, and *latissimus dorsi*. It proceeds obliquely downwards and forwards, and is connected partly to the *linea alba* and partly to the spine of the ileum. Its tendinous substance, which forms part of the *linea alba*, divides below into two columns, which leave between them a slit named the ring of the abdomen; of these columns the inferior is inserted into the os pubis of the same side, the superior decussates its fellow, and passes over to be inserted into the os pubis of the other side. That part of the external oblique muscle, which is connected to the spine of the ileum, is stretched from the anterior spinous process of that bone towards the os pubis, forming what is called *Poupart's* or *Fallopian's* ligament. This tendon is united with the strong tendinous expansion of the thigh, called *fascia lata*, which involves and sheaths the muscles of the thigh, and, proceeding to the leg, performs there the same office.

The opening, called the ring of the abdomen, formed by the tendons of this muscle, gives passage to the spermatic vessels in men, and the round
liga-

ligaments of the uterus in women. The contents of the abdomen, getting through this opening, form the inguinal hernia. Under Poupart's ligament pass the great vessels of the thigh, and this is the seat of the crural or femoral hernia.—This muscle assists the exclusion of the feces and urine, and in expiration, and bends the body forwards.

The second layer is formed by the obliquus ascendens internus. This muscle arises from the spinous and transverse processes of the three uppermost lumbar vertebræ, from the upper part of the sacrum, and from the spine of the ileum, the whole length between the posterior and superior anterior spinous process. Passing obliquely upwards, it is inserted into the cartilaginous part of all the false ribs and the two lowest of the true, to the ensiform cartilage and to the sternum. At its anterior part it becomes tendinous, and dividing, receives the rectus muscle between its separate portions. Its posterior portion is connected with the tendon of the transversalis muscle, its anterior with the linea alba. At its lowest part it is inserted into the anterior part of the os pubis. Its use is to assist the former, but it bends the trunk in the reverse direction.

The transversalis has nearly the same origins as the internal oblique. It is inserted into the cartilago ensiformis above, and into the whole length of the linea alba, except at its lowermost part. It supports and compresses the abdominal viscera.

The rectus abdominis arises from the cartilago ensiformis and the cartilages of the three lowest true ribs. In its course downwards it passes through

the sheath formed by the division of the tendon of the internal oblique, having the tendon of the external oblique without, and that of the transversalis within. The rectus is generally divided by three tendinous intersections. Below it is connected to the ossa pubis, where they are joined to each other. The use of this muscle is to compress the fore part, and more particularly the lower part, of the abdomen. It also bends the trunk forwards, or raises the pelvis towards the sternum. By being surrounded by the tendons of other muscles, it is prevented from starting from its situation.

The Pyramidales are a short pair of muscles frequently wanting; they arise from the ossa pubis, and are inserted into the linea alba about half way between them and the navel. They assist the rectus.

The anterior part of the abdomen is distinguished into several divisions, called regions. 1. The epigastric region, which reaches from the pit of the stomach to within three fingers breadth of the navel, and is bounded laterally by the hypochondria. 2. The umbilical region, which extends three fingers breadth above and below the navel, and is terminated laterally by the lumbar regions; and 3. Below the umbilical region is the hypogastric, on each side of which are the iliac regions. Still lower down is the region of the pubis.

Within the cavity of the abdomen are situated four pair of muscles. The psoas magnus arises from the side of the body and transverse process of the lowest vertebra of the back, and from those of all the vertebrae of the loins. Passing downwards through the pelvis it is inserted partly into the lesser trochanter
and

and partly into that part of the os femoris a little below it. It bends the thigh forwards, or when the thigh is fixed, as in the posture of standing, it bends the trunk forwards on the ossa femoris. The psoas parvus proceeds from the two upper vertebræ of the loins, and sending off a small long tendon, is inserted into the brim of the pelvis at the junction of the os ileum and pubis. It assists the psoas magnus in bending the loins forwards.

The iliacus internus arises from the transverse process of the last vertebra of the loins, from the inner edge of the spine of the ileum, from the edge of that bone between its anterior spinous process and the acetabulum, and from most of the hollow part of the ileum. It joins with the psoas magnus where it becomes tendinous, is inserted along with it into the smaller trochanter, and has the same effect.

The quadratus lumborum is seated further backward; it arises from the posterior part of the spine of the os ileum, and is inserted into the transverse processes of all the lumbar vertebræ, into the last rib near the spine, and by a small tendon into the side of the last vertebra of the back. Its use is to move the loins to one side, or, when both act, to draw the loins forwards.

Within the pelvis are placed the obturator internus, which arises from the internal circumference of the foramen thyroideum. Its tendon passes out of the pelvis, between the posterior sacro-ischiatic ligament and the tuberosity of the os ischium, and is inserted into the large pit at the root of the trochanter major. Its effect is to roll the os femoris obliquely outwards.

The coccygeus passes from the spinous process of the ischium to the bottom of the os sacrum and the whole length of the os coccygis. By its contraction the os coccygis is drawn forwards.

Belonging to the anus are,

The sphincter ani, which arises from the skin and fat which surrounds the verge of the anus. The fibres are gradually collected into an oval form, and surround the extremity of the rectum, which they serve to contract.

The levator ani arises from the os pubis, within the pelvis, and from the spinous process of the ischium. It is inserted into the sphincter ani, acceleratores urinæ, and the point of the os coccygis. It surrounds the extremity of the rectum and the neck of the bladder, so that joining with its fellow, they together very much resemble the shape of a funnel. It supports and draws upwards the rectum.

C H A P. XIII.

MUSCLES OF THE INFERIOR EXTREMITIES.

Muscles of the Thigh.—Of the Leg.—Of the Foot and Toes.

AS the two sides of the trunk of the body correspond, a description of one side is to be understood as applying equally to both. In the same manner the parts of the extremities have their fellows on the opposite side.

The muscles which belong to the thigh, and are situated at the anterior part of the pelvis, are,

The psoas magnus, } already described.
The iliacus internus, }

The pectinalis arises from the upper and anterior part of the os pubis, immediately above the foramen thyroideum. It is inserted into the anterior and upper part of the linea aspera of the os femoris, a little below the trochanter minor. Its use is to draw the thigh upwards and inwards, and to roll it in some degree outwards.

The triceps adductor femoris arises by three distinct heads from the ossa pubis, and is inserted into almost the whole length of the linea aspera, into a ridge above the internal condyl of the os femoris and into the upper part of that condyl. The use of this extensive muscle is, as the name expresses, to draw the thighs together; it also at the same time tends to move them upwards and to roll the thigh outwards.

The obturator externus surrounds the foramen thyroideum, and also rises from the membrane which
fills

fills up that foramen, and from the adjacent parts of the os pubis and ischium. Its fibres converge to a point, and passing outwards around the back part of the neck of the os femoris, are inserted by a strong tendon into the inner and back part of the trochanter major, adhering in their course to the capsular ligament of the thigh bone. Its use is to roll the thigh bone obliquely outwards, and to prevent the capsular ligament from being pinched.

The muscles placed at the posterior part of the pelvis, and designed for the motions of the lower extremity are, the gluteus maximus, which forms the external layer, and arises from the posterior part of the spine of the ileum, from the whole posterior surface of the os sacrum, and from the posterior sacro-ischiatic ligament; descending obliquely, it passes over the trochanter major, is firmly connected to the tendinous expansions of the tensor vaginæ femoris, and is inserted by a broad tendon into the upper and outer part of the linea aspera. The effect of this muscle is to draw the thigh backwards and a little outwards.

The gluteus medius forms another layer. It arises from the anterior superior spinous process and the dorsum of the os ileum, and is inserted into the outer and posterior part of the trochanter major. Its use is to draw the thigh outwards, and a little backwards, and to roll it, especially when it is bended.

The third layer consists of four muscles.

The gluteous minimus arises from the outer surface of the os ileum and the border of the great niche. It is inserted into the upper and anterior
part

part of the great trochanter, and assists the former muscle.

The pyriformis arises within the pelvis, from the anterior part of the os sacrum, thence becoming narrower, it passes out of the pelvis along with the posterior crural nerve, below the niche in the posterior part of the os ileum. It is inserted into a cavity at the root of the trochanter major. By its contraction it moves the thigh a little upwards, and rolls it outwards.

The gemini consists of two portions, one of which rises from the outer surface of the spine of the os ischium, the other from the tuberosity of the os ischium and posterior sacro-ischiatic ligament. It is inserted into the same part of the trochanter major with the pyriformis and obturator internus. This muscle rolls the thigh outwards, and confines the tendon of the obturator internus.

The quadratus femoris arises from the outside of the tuberosity of the os ischium, is inserted into a ridge which passes from one trochanter to the other, and rolls the thigh outwards.

The muscles seated on the thigh, and which move the leg, consist of two on the inside, one on the outside, four before, and four behind.

On the inside are,

The sartorius, which arises from the superior anterior spinous process of the ileum. This long muscle, running downwards and a little inwards, is inserted into the inner side of the tibia. It draws the legs obliquely inwards, so as to bring the legs across each other, for which reason it is called the sartorius, or the tailor's muscle.

The

The gracilis arises near the symphysis of the ossa pubis, and is inserted with the sartorius into the inner part of the tibia. It assists the sartorius in bringing the legs across, and, when they are a little bent, to assist in bending them further.

On the outside of the thigh is placed

The tensor vaginæ femoris, which arises from the external part of the anterior superior spinous process of the os ileum. It is inserted into the tendinous fascia which covers and confines the muscles of the thigh. Its use is to stretch and support the fascia, and also to roll the thigh somewhat inwards.

On the fore-part of the thigh are,

The rectus, which arises partly from the inferior and anterior spinous process of the ileum, and partly from the dorsum of the ileum, a little above the acetabulum. Passing down the middle of the os femoris it is inserted into the patella, by the intervention of which its effect, that of extending the leg, is much increased.

The vastus externus arises from the root of the trochanter major and the outer edge of the linea aspera through its whole length. It is inserted partly into the upper and outer part of the patella, and partly into the tendinous expansion, which is continued from the outside of the thigh to that of the leg. This muscle assists the former in extending the leg.

The vastus internus arises from the fore part of the os femoris, the root of the trochanter minor, and inner edge of the linea aspera. It terminates partly in the tendinous aponeurosis of the leg, and

is

is partly inserted in the inner and upper part of the patella. It also extends the leg.

The *cruræus* arises from the anterior part of the *os femoris*, between the two trochanters, but nearer the trochanter minor. It adheres firmly to the whole of the anterior part of the *os femoris*, is inserted into the middle of the patella, and assists in extending the leg.

On the posterior part of the thigh are placed

The *semitendinosus*, which arises from the tuberosity of the *os ischium*, and is inserted into the inside of the ridge of the tibia a little below its tubercle. Its effect is to bend the leg and draw it inwards.

The *femimembranosus*, which originates from the tuberosity of the *ischium*, and is inserted into the inner and back part of the head of the tibia. It bends the leg, and brings it directly backwards.

The *biceps flexor cruris* arises by two distinct heads. Of these the longer proceeds from the tuberosity of the *ischium*, and the shorter from the *linea aspera*, a little below the termination of the *gluteus maximus*. The two heads join a little above the external condyl of the *os femoris*, and are inserted by a strong tendon into the head of the fibula, forming the external ham-string. The internal is formed by the two preceding muscles.

The *popliteus* arises from the lower and back part of the external condyl of the *os femoris*, it runs over the ligament which involves the joint, and is inserted into a ridge at the upper and internal edge

edge of the tibia, a little below its head. It assists in bending the leg, and prevents the capsular ligament from being pinched.

The muscles situated on the leg, and which perform the motions of the foot, are either extensors or flexors of the foot, or extensors and flexors of the toes in general.

The extensors of the foot are: the *gastrocnemius*, which arises by two heads, one from each of the condyles of the *os femoris*. A little below the joint their fleshy bellies unite in a middle tendon, and below the middle of the tibia it terminates in a broad tendon of the following muscle.

The *soleus*, or *gastrocnemius internus*, also arises by two heads; one from the upper and back part of the head of the fibula, the other from the upper and posterior part of the tibia. The flesh of this muscle, covered by the tendon of the *gemellus*, runs down nearly as far as the extremity of the tibia, a little above which the tendons of this and of the preceding muscle unite, forming a strong cord called *tendo achillis*, which is inserted into the posterior and projecting part of the *os calcis*. The distance of the extremity of the *os calcis* from the *astragalus*, which is the center, on which the motions of the foot are performed, gives these muscles great power. Their effect is to extend the foot by bringing it more nearly into the direction of the tibia. When the foot, however, becomes the more fixed point, as in the erect posture of the body, these two muscles, by pressing the foot against the ground, raise the body; they are therefore very much employed in walking, running, and jumping, but particularly

ticularly in ascending steps, whence the fatigue felt in these muscles which form the calves of the legs by a continuance of that exercise.

The plantaris arises from the upper and back part of the external condyl of the os femoris, adhering in its descent to the capsular ligament of the knee. Passing under the gemellus, it soon terminates in a thin tendon, which is the longest in the body, and which is inserted into the inside of the back part of the os calcis. It co-operates with the former muscle in extending the foot, and also pulls the capsular ligament of the knee from between the bones, and prevents it from being pinched.

The flexors of the foot are four, two of which belong to the tibia and two to the fibula.

The tibialis anticus proceeds from the upper and fore part of the tibia, and from the interosseous ligament. Near the extremity of the tibia it sends off a round tendon, which passes under the ligamentum tarfi annulare near the inner ankle. It is inserted into the inside of the os cuneiforme internum and the posterior end of the metacarpal bone, which sustains the great toe. The effect of this muscle is to bend the foot, by drawing it upwards, and at the same time to turn it inwards.

The tibialis posticus proceeds from the upper part of the tibia near its union with the fibula, then passing through a perforation in the interosseous ligament, it continues its origin from the interosseous ligament, and from the upper half of the tibia, receiving also a few fibres from the fibula. It sends
off

off a round tendon, which passes in a groove behind the malleolus internus. It is inserted into the inner part of the os naviculare, and into the adjacent bones, at the internal and upper part of the foot. This muscle also bends the foot, and turns it inwards.

The two flexors which proceed from the fibula are,

The peroneus longus, which arises from the fore part of the head of the fibula or *perone*, and also continues to receive fibres from the external part of this bone almost as low as the ankle. Its tendon runs in a channel at the back part of the outer ankle, thence being reflected to the sinuosity of the os calcis, it runs in a groove in the os cuboides, and passing close to the bones in the sole of the foot, it is inserted chiefly into the metatarsal bone of the great toe. This muscle moves the foot outwards and a little upwards.

The peroneus brevis arises from the outer and fore part of the fibula. Its tendon passes behind the outer ankle, in which situation it is retained by the same ligament as that of the last muscle. It is inserted into the root and external part of the metatarsal bone of the little toe. This muscle also moves the foot outwards and a little upwards.

The common extensors of the toes are,

The extensor longus digitorum pedis, which arises from the upper, outer, and fore part of the tibia, interosseous ligament, and inner edge of the fibula. It divides into four tendons under the ligamentum tarfi annulare. It is inserted by four flat tendons into the roots of the first joints of the four

small

small toes. Its use is to extend all the joints of these toes. A portion of this muscle is inserted into the metatarsal bone of the little toe, assists in bending the foot, and is called the *peroneus tertius*.

The *extensor brevis digitorum pedis* arises from the fore and upper part of the *os calcis*, is inserted into the tendinous expansion at the upper part of the foot, and extends the toes.

The common flexors of the toes are,

The *flexor brevis digitorum pedis*, which arises from the lower part of the *os calcis*. Its thick fleshy belly soon divides into four tendons, which, after being pierced by those of the following muscle, are inserted into the second phalanx of the four small toes. This muscle bends the second joint of these toes.

The *flexor longus digitorum pedis* arises from the upper and back part of the tibia, some distance below its head. In its course downwards it is increased by fleshy fibres from the inner edge of the tibia, and by means of tendinous fibres is connected to the outer edge of that bone. Passing under two annular ligaments, which retain its tendon in its proper situation, it is received into a sinuosity at the inside of the *os calcis*, and about the middle of the sole of the foot divides into four tendons, which perforate those of the *flexor brevis*, and are inserted into the extremity of the last joint of the four small toes. Its use is to bend the last joint of the toes.

This muscle receives, in the sole of the foot, another, which arises from the inside of the os calcis, and which increases its strength.

The *lumbricales pedis* are four small muscles in the sole of the foot, so called from their resemblance in size and appearance to earth-worms; they arise from the four tendons of the *flexor digitorum longus*, and are inserted into the inside of the first joint of the four small toes. These muscles render the flexion of the toes more extensive, and draw them inwards.

The muscles situated chiefly on the foot are those designed for the motions of each of the toes in particular. To the great toe belong five muscles. Of these, one extends it, two bend it, one draws it outwards, and another inwards.

The little toe, besides the common flexors and extensors, has two muscles proper to itself. One of these draws it outwards, and the other contributes to its flexion.

Between the metatarsal bones are also seated seven muscles, called the *interossei interni et externi*. The internal *interossei* are three in number; their use is to draw the three smaller toes towards the great toe. The external *interossei* are four; of these, the first serves to move the fore-toe towards the great-toe; the other three draw the three toes next the great toe outwards. All the *interossei* assist in extending the toes.

The *transversalis pedis* arises from the under part of the anterior extremity of the metatarsal bone of the great toe, and terminates at that of the metatarsal bone of the little toe. By the contraction
of

of this muscle the great and little toes are brought nearer.

The muscles situated in the foot are covered and protected by a strong tendinous expansion, which passes from the os calcis to the first joints of all the toes.

C H A P. XIV.

MUSCLES OF THE SUPERIOR EXTREMITIES.

*Scapular Muscles.—Muscles of the Fore-arm.—Of the Hand.—
Of the Fingers.*

THE pectoralis major and latissimus dorsi have already been described.

The muscles which are seated on the scapula, and which are inserted into the os humeri, are,

The supraspinatus, which arises, as its name expresses, from that part of the scapula which is above its spine; it passes under the acromion, adhering to the capsular ligament of the os humeri, and is inserted into the large tuberosity on the head of that bone. Its use is to raise the arm upwards, and to draw the capsular ligament from between the bones, so that it may not be hurt by compression.

The infraspinatus, which originates from all that part of the base of the scapula that is between its spine and inferior angle; and also from the spine as far as the cervix scapulæ. Its tendon, running forwards, is connected with the capsular ligament, and terminates in the middle and upper part of the protuberance on the head of the os humeri. This muscle rolls the humerus outwards, supports the arm when raised, and also assists in raising it, and pulls the ligament from between the bones.

The teres minor arises from the inferior costa of the scapula, and is inserted into the back part of the tuberosity

tuberosity on the head of the os humeri. Its use is to roll the humerus outwards and draw it backwards, and by its connection with the capsular ligament of the os humeri, to draw it from between the bones.

The *teres major* arises from the inferior angle and inferior costa of the scapula; its fleshy fibres are continued over part of the *infraspinatus* muscle, to which they firmly adhere. It is inserted, by a broad and thin tendon, along with the *latissimus dorsi*, into the ridge at the inner side of the groove for lodging the tendon of the long head of the biceps. Its effect is to roll the humerus inwards, and draw it backwards and downwards.

The *deltoides* arises from the clavicle, process acromion, and the spine of the scapula; from these origins its fasciculi converge, forming a covering to the anterior part of the joint of the os humeri. It is inserted into a rough protuberance in the outer side of the os humeri. The chief effect of this muscle is to raise the arm; but from the different direction of its fibres, it may also move it backwards or forwards.

The *coraco-brachialis* arises from the fore part of the coracoid process of the scapula, is inserted into the middle and inner side of the os humeri, and moves the arm upwards and forwards.

The *subscapularis* arises from the whole internal surface of the scapula; after being connected to the capsular ligament, it is inserted into the upper part of the small internal protuberance at the head of the os humeri. It rolls the os humeri inwards,

draws it to the side of the body, and draws the capsular ligament from between the bones.

The muscles situated on the os humeri, and which move the fore-arm, are only four; two being placed before for the flexion of the joint, and two behind for its extension. Those placed before are,

The biceps flexor cubiti, which consists of two heads, which unite about the middle of the os humeri. Of these the shorter rises from the coracoid process of the scapula; the longer and outermost begins from the upper edge of the glenoid cavity of the scapula, passes over the head of the os humeri within the joint, and in its descent without the joint is inclosed, by a membranous ligament, in a groove near the head of the os humeri. This muscle is inserted, by a strong roundish tendon, into the tubercle on the upper end of the radius internally. Its effects are to bend the fore arm, and to turn the radius outwards, and so bring the palm of the hand uppermost. Part of the tendon proceeding from this muscle is also spent in a tendinous expansion, which covers all the muscles at the inside of the fore arm, and joins with another tendinous membrane, which is sent off behind from the triceps extensor cubiti. The use of these expansions, as in other parts of the body, is to confine the motions of the muscles, to protect them, and to give origin to a number of fibres.

The brachialis internus arises from the os humeri at each side of the insertion of the tendon of the deltoides. Being closely applied to the inferior and inner part of the os humeri, it runs over the joint; is firmly attached to the ligament, and is inserted
into

into the coronoid process of the ulna. It assists the former muscle in bending the fore-arm.

Behind are

The triceps extensor cubiti, which consists of three heads; of these one proceeds from the inferior costa of the scapula, another from the upper and outer part of the os humeri, and the third from the back part of that bone. These three heads, when united, form a large muscle, which is closely applied to the posterior part of the humerus, from which they receive some muscular fibres. This muscle is fixed to the upper and outer part of the olecranon of the ulna.

The anconæus arises from the external condyle of the os humeri, and is inserted into a ridge on the outer and posterior edge of the ulna. It assists in extending the fore arm.

The muscles situated on the fore arm may be divided into four orders: 1. Flexors and extensors of the whole hand. 2. Flexors and extensors of the fingers. 3. Supinators and pronators, or those which roll the radius on the ulna. 4. Flexors and extensors of the thumb and fore finger.

The first order consists of three flexors and three extensors. The flexors are,

The palmaris longus, which arises from the inner condyle of the os humeri, and is inserted partly into the annular ligament, which confines the tendons seated in the wrist, and partly into the tendinous expansion, which covers the palm of the hand. This muscle bends the wrist and stretches this membrane.

The palmaris brevis, which originates from the annular ligament and tendinous expansion on the palm of the hand, and is inserted into the os pisiforme, and the skin covering the abductor minimi digiti. It assists in contracting the palm of the hand. This small muscle is commonly considered as belonging to the former.

The flexor carpi radialis proceeds from the inner condyle of the os humeri, and is inserted into the metacarpal bone of the fore finger. It bends the hand and assists in its pronation, that is, in turning the palm downwards.

The flexor carpi ulnaris arises also from the internal condyle of the os humeri, and also from the outer side of the olecranon. It is inserted into the os pisiforme, and assists in bending the wrist.

The extensors of the whole hand are,

The extensor carpi radialis longior, which arises from the lower part of the external ridge of the os humeri, above its external condyle. It is inserted into the upper part of the metacarpal bone, which supports the fore finger. Its effect is to extend the wrist and bring the hand backwards.

The extensor carpi radialis brevior arises from the outer part of the external condyle of the humerus, and from the ligament which connects the radius to it. It is inserted into the upper part of the metacarpal bone of the middle finger, and extends the wrist.

The extensor carpi ulnaris arises from the external condyle of the os humeri, and also receives an accession of fibres in its progress from the ulna.

ulna. Its round tendon is confined by a membranous sheath in a groove, which is situated at the extremity of the ulna. It is inserted into the upper part of the metacarpal bone of the little finger, and assists in extending the wrist.

The flexors and extensors of the four fingers are,

The flexor sublimis perforatus, which arises from the internal condyle of the os humeri, the inner edge of the coronoid process of the ulna, and the upper and anterior part of the radius. It sends off four tendons before it passes under the ligament of the wrist, which being divided for the passage of the tendons of the following muscle, are inserted into the anterior and upper part of the second bone of each finger. It bends the second joints of the fingers.

The flexor profundus perforans, which originates from the upper part of the ulna, and from a considerable part of the interosseous ligament. It divides into four tendons, which pass through the flits in the tendons of the preceding muscle, and are inserted into the upper part of the last bone of the four fingers. Its use is to bend the last joint of the fingers.

The lumbricales arise from the four tendons of the preceding muscle, and are inserted into the outer sides of the broad tendons of the interossei muscles. They increase the flexion of the fingers.

The extensor digitorum communis arises from the outer condyle of the os humeri, and is inserted into the posterior part of all the fingers by a tendinous expansion. It extends the joints of all the fingers.

The

The muscles, which roll the radius on the ulna, are,

The supinator radii longus, which arises from the external ridge of the os humeri, above the external condyle. It is inserted into the outer side of the inferior extremity of the radius. Its effect is to roll the radius outwards, and consequently to turn the palm of the hand upwards.

The supinator radii brevis, which arises from the external condyle of the os humeri, and posterior surface and outer edge of the ulna. It is inserted into the head, neck, and tubercle of the radius. It rolls the radius outwards, and turns the palm of the hand upwards.

The pronator radii teres, which originates from the internal condyle of the os humeri and coronoid process of the ulna. It is inserted into the posterior part of the radius, about the middle of that bone. Its effect is to roll the radius, with the hand, inwards, and consequently to turn the back of the hand upwards, or to lay the hand prone.

The pronator radii quadratus arises from the inner and lower part of the ulna. Its fibres, running transversely, are inserted into the anterior part of the radius opposite to their origin.

For the motion of the thumb are placed in the fore-arm,

The flexor longus pollicis manus, which originates from the upper and fore part of the radius; its tendon passes under the ligament of the wrist, and is inserted into the last joint of the thumb, which it serves to bend.

The extensor ossis metacarpi pollicis manus, which arises from the middle and posterior part of the
the

the ulna, from the middle and posterior part of the radius, and from the interosseus ligament. It is inserted into the os trapezium and upper back part of the metacarpal bone of the thumb. Its effect is to extend the metacarpal bone of the thumb outwardly.

The extensor primi internodii arises from the posterior part of the ulna, and from the interosseous ligament. It is inserted into the posterior part of the first bone of the thumb, which it extends obliquely outwards.

The extensor secundi internodii, arises from the middle and back part of the ulna, and from the interosseous ligament, and is inserted into the last bone of the thumb, which it extends obliquely backwards.

To the fore finger belongs

The indicator, which begins from the posterior part of the ulna, about the middle of that bone. Its tendon, accompanying that of the extensor digitorum communis, which belongs to the same finger, they are inserted together into its upper part. Its effect is to extend the fore finger, whence its name of *indicator*, as that is the finger with which we usually point at any object of attention.

The muscles seated in the hand may be divided into those of the thumb and those of the fore and little fingers.

The flexor brevis pollicis manus arises from the os trapezoides, annular ligament, os magnum, and os unciforme, and is inserted into the second joint of the thumb, which it serves to bend.

The

The *flexor ossis metacarpi pollicis*, or *opponens pollicis*, arises from the *os trapezium* and *ligamentum carpi annulare*. It is inserted into the under and anterior part of the first bone of the thumb. Its effect is to bring the thumb inwards, so as to place it in opposition to the fingers.

The *abductor pollicis manus* commences from the *ligamentum carpi annulare* and from the *os trapezium*, and is inserted into the outer side of the root of the first bone of the thumb. Its use is to draw the thumb from the fingers.

The *adductor pollicis manus* arises from the metacarpal bone which sustains the middle finger, and is inserted into the inner part of the root of the first bone of the thumb. This muscle pulls the thumb towards the fingers.

The thumb has, therefore, in all, eight muscles, four seated in the fore-arm and four in the hand. Of the whole eight, three are flexors, three extensors, one is an abductor, the other an adductor.

One muscle, the indicator, proper to the fore-finger, and seated in the fore-arm has been already described; another muscle proper to this finger is seated in the hand; it is called

The *abductor indicis manus*, and arises from the inner side of the first bone of the thumb and from the *os trapezium*, and is inserted into the first bone of the fore-finger. It serves to bring the fore-finger towards the thumb.

To the little finger belong

The *abductor minimi digiti*, which arises from the *os pisiforme* and the adjacent part of the annular ligament. It is inserted into the side of the first bone

bone of the little finger, which it draws from the rest.

The adductor metacarpi minimi digiti manus, which arises from the os unciforme and the adjacent part of the annular ligament; it is inserted into the anterior part of the metacarpal bone of the little finger, which it draws towards the rest.

The flexor parvus minimi digiti arises from the os unciforme, and from the ligament of the wrist near it, and is inserted into the first bone of the little finger. It bends the little finger, and assists the adductor.

Between the metacarpal bones there are four internal and three external muscles, named interossei. They are inserted into the roots of the fingers. The interossei interni extend the fingers, and move them towards the thumb, except the third, which draws the middle finger from the thumb. The interossei externi also extend the fingers; but the first draws the middle finger inwards, the second draws it outwards, and the third draws the ring-finger inwards.

The figure in Plate IV. represents the first layer of muscles situated on the anterior part of the whole body, immediately under the common integuments, and tendinous fasciæ.

MUSCLES situated on the HEAD and NECK.

a, The anterior fleshy belly of the occipito-frontalis situated on the os frontis.

Above *a*, the tendinous aponeurosis of the occipito-frontalis, covering the upper part of the parietal bones.

b, Attollens aurem.

Under

Under it the tendinous aponeurosis covering the temporal muscle.

Anterior auris between *c* and the ear.

c, Orbicularis palpebrarum.

Its tendon is seen at the inner canthus, fixed to the nasal process of the superior maxillary bone.

Levator labii superioris alæque nasi.

Seen divided into two portions running down along the side of the nose; and on the outside of it, the levator anguli oris.

Next this, the

Zygomaticus minor.

Farther outwards,

Zygomaticus major.

On the ala and tip of the nose, the Compressor naris.

d, Depressor anguli oris.

And beneath it, a portion of the depressor labii inferioris.

e, Orbicularis oris

f, Platysma-myoides.

Behind *f*, the sterno-cleido-mastoidæus is seen through the platysma-myoides.

T R U N K.

a, Pectoralis major.

The upper part of it is covered by the origin of the platysma-myoides.

b, Serratus magnus.

The other portions resemble this.

c, Latissimus dorsi.

d, Obliquus externus descendens.

e, Linea

e, Linea semilunaris.

f, Linea alba.

Below *f*, the umbilicus.

Between *e* and *f*, the rectus abdominis; and, at the inferior part of the linea alba, opposite to *g*, the pyramidales appear through the tendons of the oblique muscles.

g, Ring of the external oblique muscle; with the spermatic chord, passing through it, and covered by the cremaster muscle.

SUPERIOR EXTREMITY.

a, Deltoides.

Above the clavicle, a portion of the trapezius is seen.

b, Biceps flexor cubiti.

At the bending of the arm is seen its tendon going towards the radius, and the part, from which the tendinous aponeurosis that covers the fore-arm, is cut off.

On the inside of the biceps, part of the triceps extensor cubiti; and on the outside, part of the brachialis internus.

c, Supinator radii longus.

d, Pronator teres.

e, Palmaris longus.

f, Palmaris brevis.

On the palm of the hand, the aponeurosis palmaris is seen extended from the annular ligament at the wrist, to the roots of the metacarpal bones of the four fingers.

g, Flexor carpi radialis.

h, Part of the flexor sublimis perforatus.

i, In-

- i*, Insertion of the flexor carpi ulnaris.
k, Abductor pollicis.

INFERIOR EXTREMITY.

- a*, Tensor vaginæ femoris, the vagina or tendinous fascia being cut off.

On the outside of it a portion of the glutæus maximus.

- b*, Part of the iliacus internus.

On the inside of it, between *b* and *c*, part of the psoas magnus.

- c*, Pectinalis.

- d*, Triceps longus.

- e*, Gracilis.

- f*, Sartorius.

- g*, Rectus cruris.

Its tendon is seen inserted into the patella, from which a strong tendon is sent to be fixed to the tubercle of the tibia.

- h*, Vastus externus.

- i*, Vastus internus.

- k*, Tibialis anticus.

- l*, Peronæus longus.

On the outside of it, a portion of the solæus.

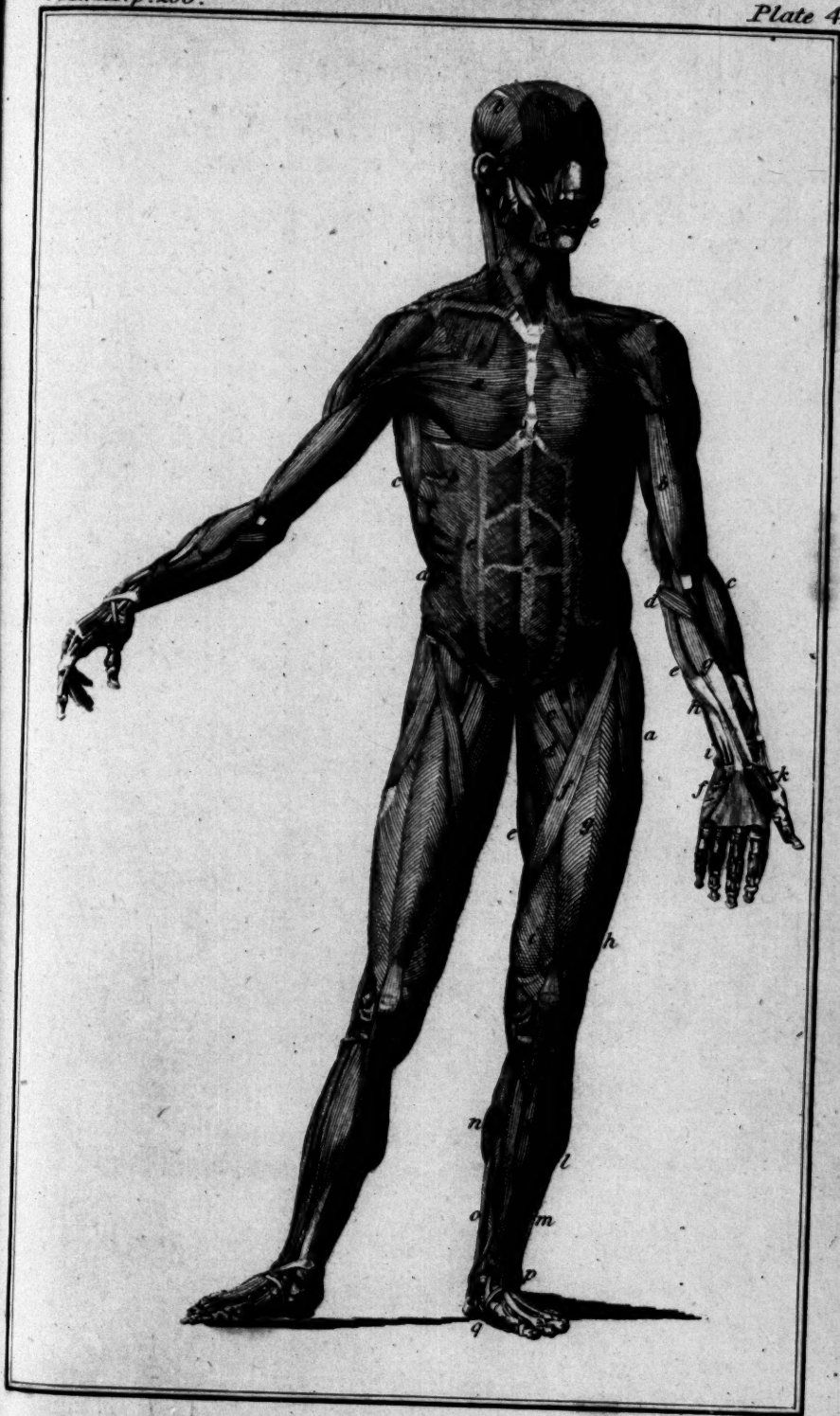
- m*, Extensor longus digitorum pedis, with the peronæus tertius, and extensor proprius pollicis pedis.

- n*, Gastrocnemius externus, or gemellus.

- o*, Solæus.

- p*, Ligamentum tarfi annulare.

- q*, Abductor pollicis pedis.





The figure in Plate V. represents the second layer of muscles on the anterior part of the whole body.

MUSCLES situated on the HEAD and NECK.

a, Corrugator supercilii.

b, Temporalis.

c, Masseter.

d, Levator anguli oris.

e, Buccinator.

f, Orbicularis oris.

Opposite to the right ala nasi, the portion of this muscle, which Albinus names,

Nasalis labii superioris.

g, Depressor labii inferioris.

h, Sterno-cleido-mastoidæus, which is

Seen below, arising from the sternum and clavicle, by two heads.

i, Sterno-hyoidæus.

On the outside of it, the

Omo-hyoidæus.

Further out, a portion of the

Hyo-thyroidæus.

k, Levator scapulæ.

T R U N K.

a, Subclavius.

b, Pectoralis minor.

c, Serratus magnus.

d, Rectus abdominis, divided into several fleshy portions by its tendinous intersections.

e, Pyramidalis.

f, Obliquus ascendens internus.

g, Spermatic cord, with the origin of the cremaster muscle.

SUPERIOR EXTREMITY.

a, Biceps flexor cubiti.

b, Short head of the biceps.

Beneath the upper part of it, a portion of the coracobrachialis.

Beneath the under part, a portion of the brachialis internus.

c, Long head of the biceps.

At the bending of the arm, the tendon of the biceps, and the place where the tendinous aponeurosis was cut from it, are seen.

d, Extensor carpi radialis longior.

Beneath it a portion of the Extensor carpi radialis brevior.

e, Flexor sublimis perforatus.

f, Insertion of the extensor carpi ulnaris.

g, Extensors of the thumb.

h, Opponens pollicis.

On the inside of it, a portion of the Flexor pollicis brevis.

i, Tendon of the flexor longus pollicis manus, after passing through the flexor brevis pollicis manus.

k, Abductor minimi digiti manus.

l, Flexor parvus minimi digiti manus.

m, Ligamentum carpi annulare.

INFERIOR EXTREMITY.

a, Iliacus internus.

Between *a* and *b*, part of the psoas magnus.

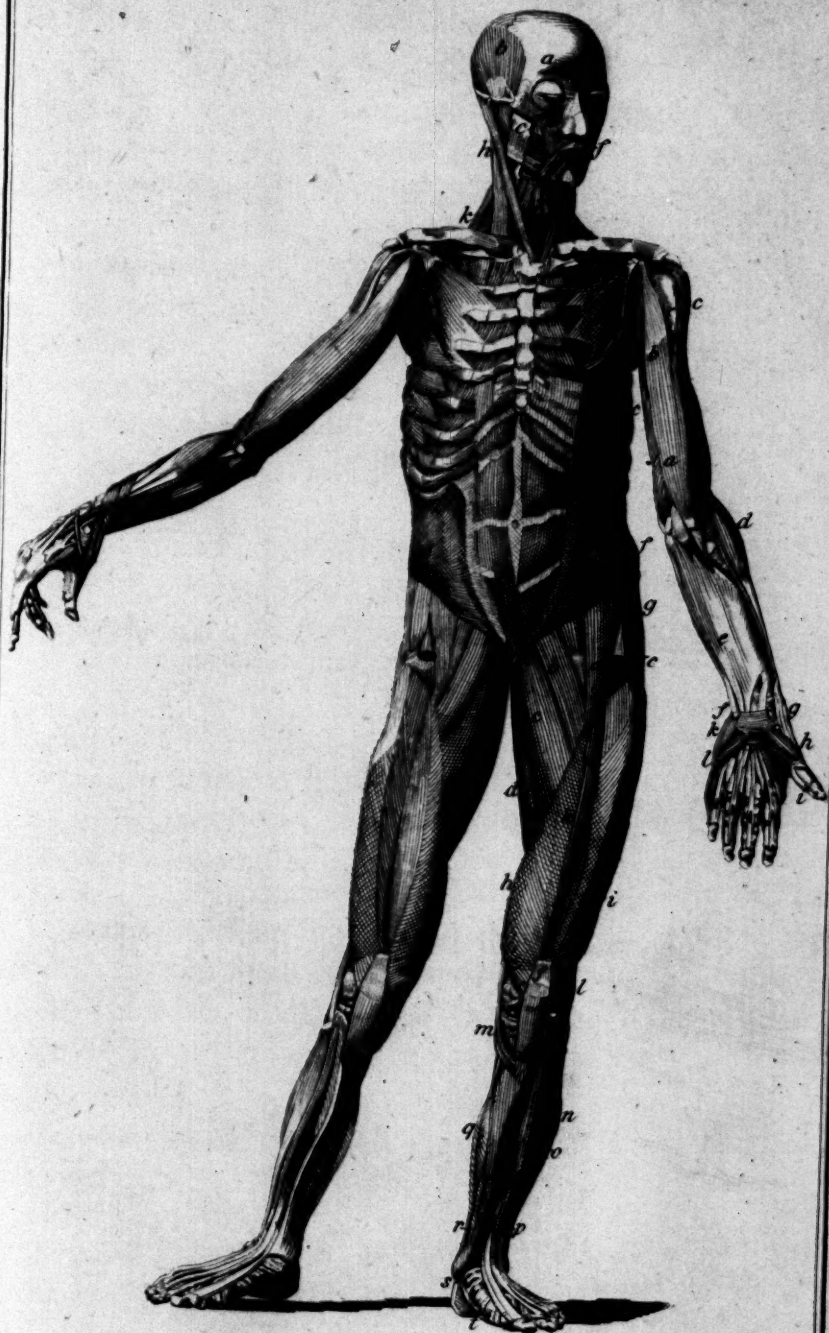
b, Pectinalis.

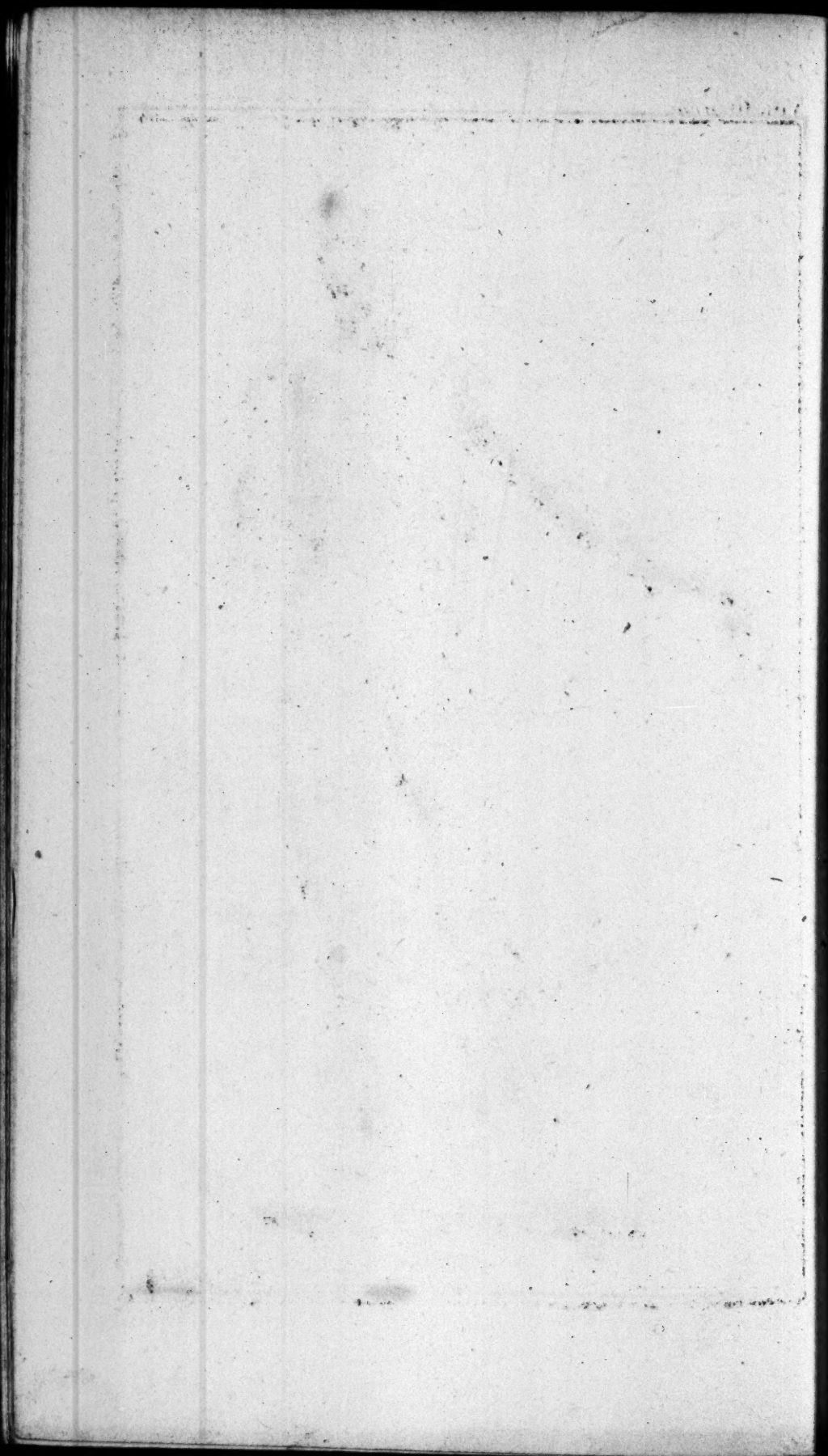
c, Triceps longus.

d, Gracilis.

e, Rectus cruris cut off near its origin.

f, Tendon





- f*, Tendon of the rectus cruris cut off above the patella, from which a strong tendon is sent to be inserted into a tubercle of the tibia.
- g*, Portion of the glutæus medius.
On the inside of it, part of the glutæus minimus.
- h*, Vastus internus.
- i*, Vastus externus.
- k*, Cruræus.
- l*, Insertion of the biceps flexor cruris into the fibula.
- m*, Tendons of the gracilis and semitendinosus inserted into the tibia.
- n*, Solæus.
- o*, Peronæus longus.
- p*, Extensor longus digitorum, with the peronæus tertius on the outside, and extensor pollicis proprius on the inside.
- q*, Solæus.
- r*, Flexor longus digitorum.
- s*, Tendons of the tibialis posticus and flexor longus digitorum pedis.
- t*, Flexor brevis digitorum pedis.

The figure in Plate VI. represents the third layer of muscles, with some of the ligaments, cartilages, and naked bones on the anterior part of the whole body.

- a*, Depressor labii superioris alæque nasi.
- b*, Orbicularis oris, after most of the muscles, which are fixed to it, and assist to form it, have been taken away.
- c*, Buccinator.
Above *c*, part of the pterygoidæus externus is seen passing behind the coronoid process of the lower jaw.

d, Levator labii inferioris.

e, Sterno-thyroidæus.

Immediately above, and seemingly the continuation of it, the

Hyo-thyroidæus.

f, Scalenus anticus.

Contiguous to it, on the inside, the Scalenus medius.

Above it, a portion of the Trachelo-mastoidæus.

Between the scalenus anticus, and sterno-thyroidæus, and hyo-thyroidæus, the Rectus capitis anterior major, and Longus colli.

TRUNK.

a, Third row of external intercostal muscles.

The rest appear in the same manner between the other ribs.

b, Third row of internal intercostal muscles.

The rest appear between the other ribs.

c, Transversalis abdominis.

d, The place from which the inferior part of the tendon of the transversalis, that passes before the rectus and pyramidalis muscles, is cut off.

Between these portions of each side, the peritonæum is laid bare, and the ligaments of the bladder, which were formerly the umbilical arteries and urachus.

Between this portion and the os pubis, the spermatic cord is seen cut.

e, The inferior edge of the upper part of the tendon of the transversalis, which passes behind the rectus,

rectus, and immediately adheres to the peritonæum.

- f*, The anterior lamella of the internal oblique, which joined the tendon of the external to pass over the rectus.

Between *f* and *g*, the posterior lamella of the internal oblique, joining with the tendon of the transversalis, to pass behind the rectus.

- g*, The place at the linea alba, from which the tendon of the external oblique, and anterior lamella of the internal, were cut off.

At *g*, Umbilicus,

SUPERIOR EXTREMITY.

- a*, Subscapularis.

- b*, Teres minor.

- c*, Coraco-brachialis.

The part from which the short head of the biceps flexor cubiti was cut off from it, is seen at its upper end.

- d*, Brachialis internus.

- e*, Brachialis externus, or third head of the triceps.

- f*, Extensor carpi radialis longior, and with it the extensor carpi radialis brevior.

Both these are distinctly seen in the right hand.

Between the tendon of the brachialis internus and extensor radialis, the

Supinator radii brevis is seen.

- g*, Flexor longus pollicis manus, with the fleshy portion of it which arises from the internal condyle of the os humeri.

b, Flexor profundus perforans, which splits into four tendons, which pass under the ligamentum carpi annulare.

i, Pronator quadratus.

k, Adductor minimi digiti manus.

l, One of the lumbricales.

The other three appear in the same manner, along the tendons of the flexor profundus. Behind these, the internal interossei are seen.

INFERIOR EXTREMITY.

a, Glutæus minimus.

b, Iliacus internus.

On the inside of it, between *b* and *c*, the psoas magnus.

c, Obturator externus.

d, Adductor brevis femoris.

e, Adductor magnus femoris.

f, Gracilis; which is

Seen inserted into the inside of the head of the tibia.

g, The short head of the biceps flexor cruris.

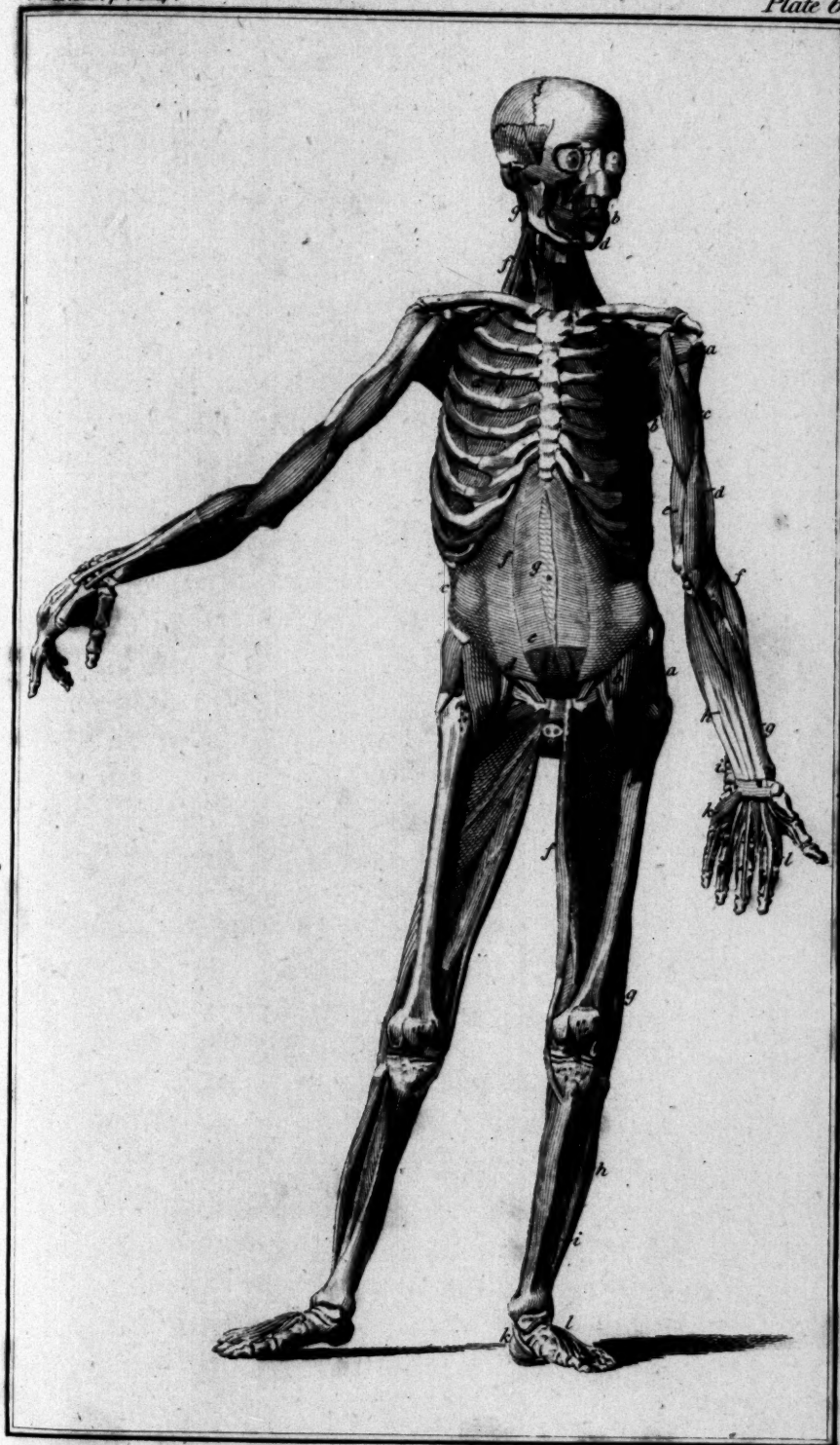
h, Peronæus longus.

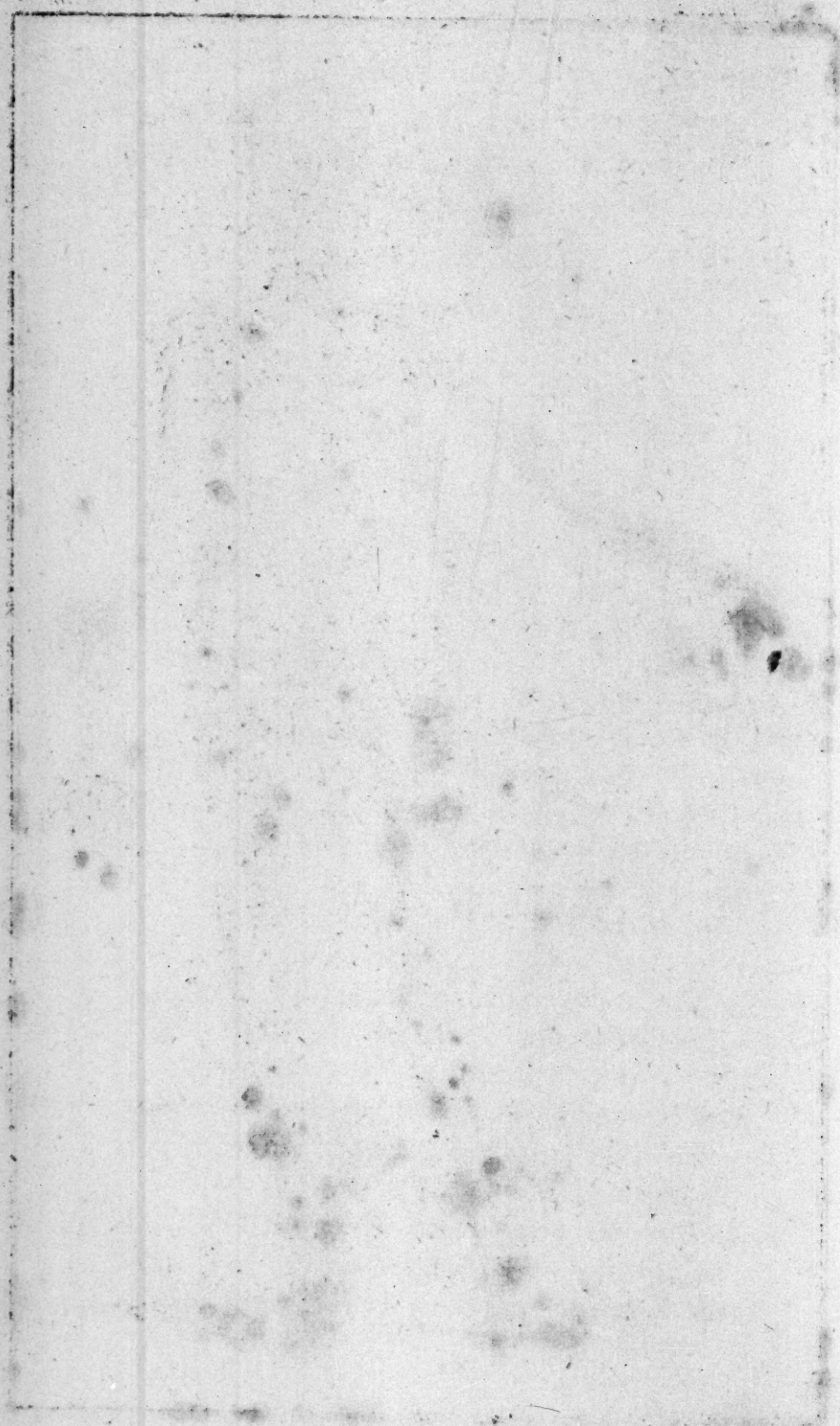
i, Peronæus brevis.

Between these two peronæi and tibia, the tibialis posticus is seen.

k, Tendon of the tibialis posticus, covering the tendon of the flexor longus digitorum pedis.

l, Extensor brevis digitorum pedis.





The figure in Plate VII. represents a back view of the muscles, which are immediately situated below the common integuments.

HEAD and NECK.

- a*, Part of the occipito-frontalis muscle, with its aponeurosis.
- b*, Attollens aurem.
- c*, Anterior auris.
- d*, Retrahentes auris.

TRUNK.

- a*, Trapezius, or cucularis.
- b*, Its tendinous edge joining with its fellow in the nape of the neck, which is called *ligamentum nuchæ* or *colli*.
- c*, The fleshy belly of the latissimus dorsi.
- d*, The tendon of the latissimus dorsi, which arises in common with the serratus posticus inferior.
- e*, Part of the obliquus externus abdominis.

SUPERIOR EXTREMITY.

- a*, Deltoides.
- b*, Infraspinatus, with a portion of the teres minor and major below it,
- c*, Triceps extensor cubiti.
Its tendon is seen inserted into the head of the ulna, called *olecranon*; and, on the inside of it, the *anconæus*.
- d*, Extensor carpi radialis longior, covered by a portion of the supinator radii longus; and, under it, a portion of the extensor carpi radialis brevior.

- e*, Extensor digitorum communis manus, which splits into four tendons, and pass with the indicator, under the ligamentum carpi annulare externum, at the extremities of the metacarpal bone, under ligaments proper to themselves; and are lost in a broad tendon, which covers the back of the four fingers.
- f*, Extensor ossis metacarpi pollicis manus.
- g*, Extensor primi internodii pollicis manus.
- h*, Extensor secundi internodii pollicis manus.
- i*, Extensor carpi ulnaris.
- k*, Part of the flexor carpi ulnaris.

Under it, part of the

Flexor profundus perforatus.

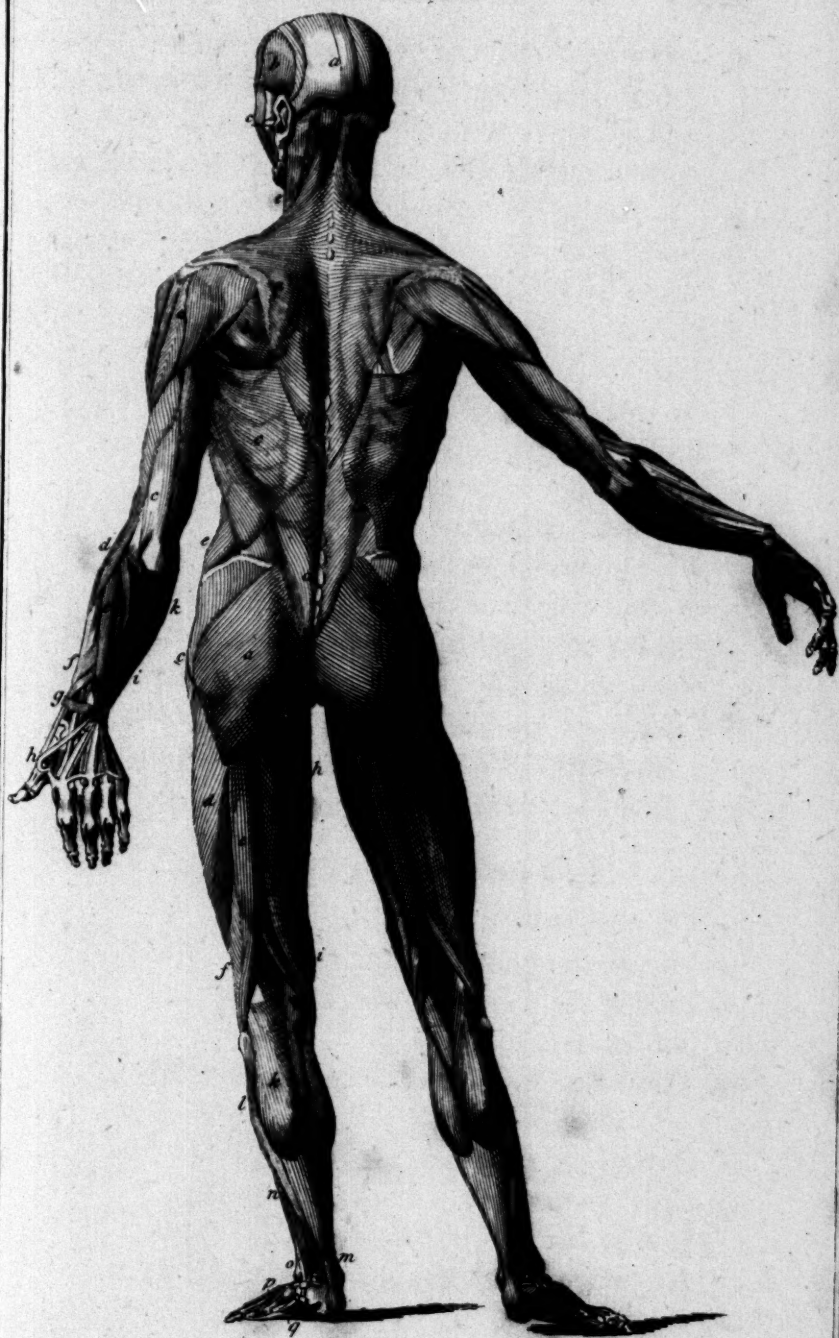
And on the inside, part of the

Flexor sublimis perforatus, which are more distinctly seen on the right fore-arm. Likewise, on the right hand, are seen part of the abductor pollicis manus, abductor minimi digiti manus, and the aponeurosis palmaris.

INFERIOR EXTREMITY.

- a*, Glutæus maximus.
- b*, Part of the glutæus medius.
- c*, Part of the tensor vaginæ femoris.
- d*, Vastus externus.
- e*, The long head of the biceps flexor cruris :
And beneath it,
- f*, Part of the short head.
- g*, Semitendinosus :
And beneath it, on each side,
A portion of the semimembranosus is seen.
- h*, Gracilis.

On



On the outside of it,

A portion of the adductor magnus is seen.

i, A small part of the vastus internus.

k, Gastrocnemius externus, or gemellus ;

And within its outer head,

A portion of the plantaris.

l, Solæus or gastrocnemius internus.

m, Tendo Achillis, with the plantaris.

n, Peronæus longus.

o, Peronæus brevis ; between it and the tendo Achillis, a portion of the flexor longus digitorum pedis.

p, Tendons of the extensor longus digitorum pedis, with the peronæus tertius, passing under the ligamentum tarfi annulare ; and the flexor brevis digitorum pedis is seen beneath them.

q, Abductor minimi digiti pedis ; and above it the tendons of the peronæus longus and brevis, passing under proper ligaments of their own.

The figure in Plate VIII. represents the second layer of the muscles on the back-part of the body.

HEAD and NECK.

a, Temporalis ; its tendon is seen passing below the zygoma.

b, Masseter.

c, Splenius capitis et colli.

d, Portion of the complexus.

e, Levator scapulæ, or the musculus patientiæ.

TRUNK.

T R U N K.

- a*, Rhomboides major.
- b*, Rhomboides minor :
And immediately above it, the upper edge of the
serratus posticus superior is seen.
- c*, The serratus posticus superior on the right side.
- d*, Serratus posticus inferior.
- e*, Part of the spinalis dorsi.
- f*, Part of the longissimus dorsi.
- g*, Part of the sacro lumbalis.
- h*, Serratus magnus.
- i*, The broad tendon, by which the latissimus dorsi
begins, and from which the tendon of the serratus
posticus inferior is inseparable.
- k*, Part of the obliquus internus ascendens abdominis.
- l*, The sphincter ani, fixed to the point of the os coc-
cygis ; at the side of which the coccygæus,
and a portion of the levator ani, are seen,
&c.

S U P E R I O R E X T R E M I T Y.

- a*, Supra-spinatus.
- b*, Infra-spinatus.
- c*, Teres minor.
- d*, Teres major.
- e*, Triceps extensor cubiti.
- f*, Its head called *longus*.
- g*, The *brevis* : And,
- h*, A small portion of the third head, named *bra-*
chialis externus.
- i*, The tendon of the triceps, inserted into the ole-
cranon.

k, Part

- k*, Part of the brachialis internus.
 - l*, Anconæus, which seems to be continued from that part of the brachialis externus immediately above it.
 - m*, Extensor carpi radialis longior; and beneath it, the brevior: both are seen at the wrist, inserted into the metacarpal bones of the fore and middle fingers.
 - n*, Flexor carpi ulnaris.
 - o*, Part of the supinator radii brevis.
 - p*, Extensor ossis metacarpi pollicis manus.
 - q*, Extensor primi internodii pollicis manus.
 - r*, Extensor secundi internodii pollicis manus.
 - s*, Indicator, inserted into the root of the first joint of the fore-finger.
 - t*, One of the three external interossei manus. The other two are distinctly seen without letters.
 - u*, One of the tendons of the extensors of the fingers cut; and the same is seen in each of the other three fingers, joining with the tendons and aponeuroses of the interossei and lumbricales, and spread upon the back of the fingers.
- N. B.* On the right hand, part of the flexors of the fingers, the abductor [pollicis and minimi digiti, are seen.

INFERIOR EXTREMITY.

- a*, Glutæus medius.
- b*, Pyriformis.
- c*, The two muscles called *gemini*, between which the tendon and fleshy belly of the obturator internus passes over the tuberosity of the os ischium,

ischium, are seen within the pelvis, partly covered by the coccygæus and levator ani.

d, Quadratus femoris.

e, Vastus externus.

f, f, Parts of the triceps magnus.

g, Long head of the triceps flexor cruris, and beneath it part of the short head is seen.

b, Semitendinosus, and beneath it parts of the semimembranosus are seen on each side of it.

i, Gracilis,

k, A small portion of the vastus internus.

l, Poplitæus.

m, The fleshy belly of the plantaris; and its long slender tendon is seen passing over the inside of the solæus.

n, Solæus.

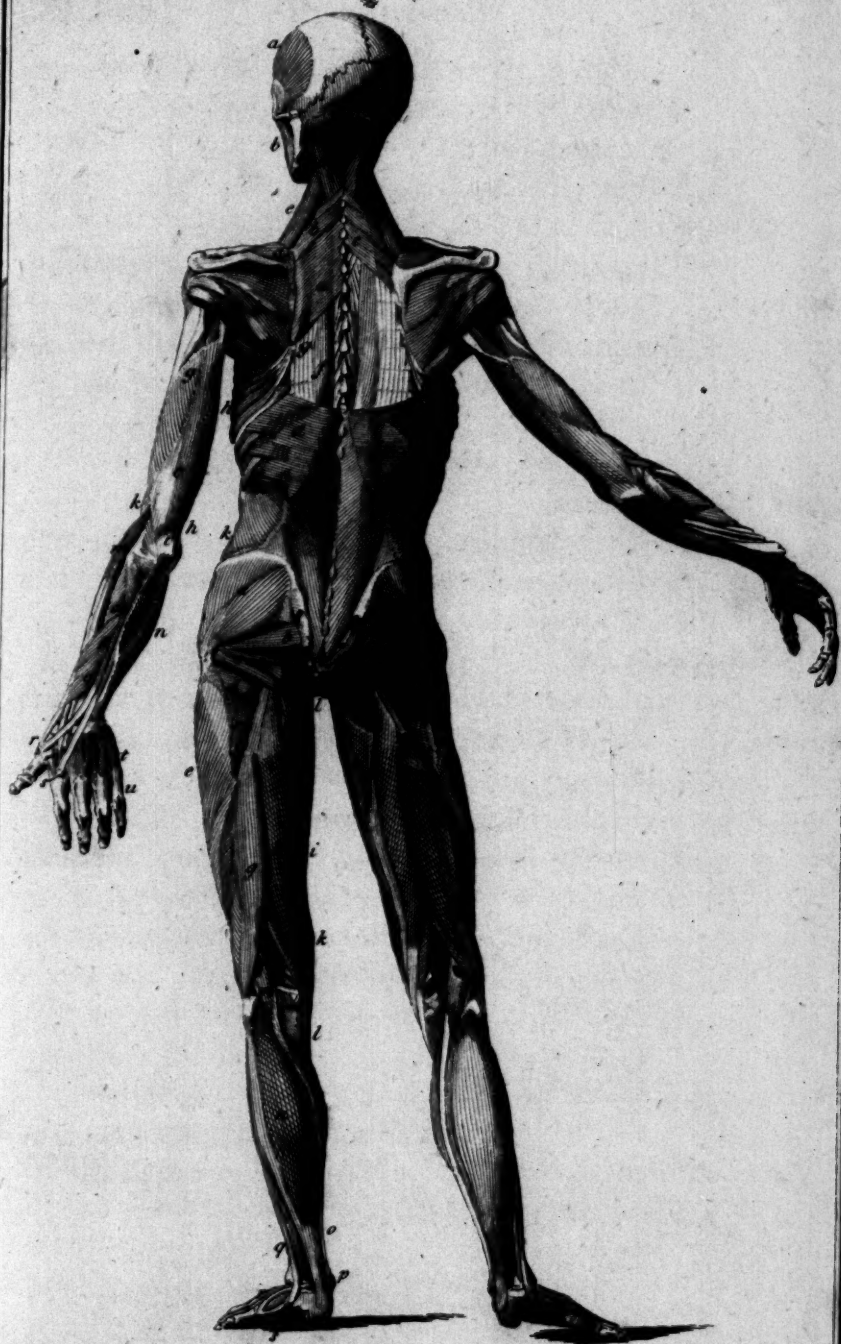
o, The place where the tendon of the gemellus was cut off; but the flesh of the solæus runs farther down.

p, Tendo Achillis, with the plantaris.

q, Peronæus longus, passing at the outer ankle to the sole of the foot; beneath it, the peronæus brevis to the root of the metatarsal bone of the little toe; and, between it and the tendo Achillis, a portion of the flexor longus digitorum pedis.

r, Tendons of the extensor longus digitorum pedis, with the peronæus tertius; and beneath these, the extensor brevis digitorum pedis.

s, Flexor brevis minimi digiti pedis,



The figure in Plate IX. represents the third layer of muscles on the posterior part of the body, with some of the ligaments and naked bones.

MUSCLES *on the* HEAD *and* NECK.

- a*, Part of the buccinator.
- b*, Complexus.
- c*, Trachelo-mastoidæus; on the outside of it, the transversalis colli.
- d*, Scalenus medius.
- e*, Scalenus posticus.

TRUNK.

- a*, Spinalis dorsi; and beneath it, the multifidus spinæ.
- b*, Longissimus dorsi, which sends off a fleshy slip to the trachelo-mastoidæus.
- c*, Sacro lumbalis, with the cervicalis descendens sent off from it along the side of the neck, and outside of the transversalis colli.
- d*, Semispinalis dorsi.
- e*, Transversalis abdominis.

N. B. The spaces between the spinous processes of the vertebræ have muscular fasciculi between them, particularly those of the neck; and are named *interspinales colli*, *dorsi*, and *lumborum*; but those of the back seem to be tendinous and ligamentous.

SUPERIOR EXTREMITY.

- a*, Teres major.
- b*, Part of the coraco-brachialis.
- c*, Part of the brachialis internus.

d, The

d, The third head of the triceps extensor cubiti, called *brachialis externus*, after the longus and brevis have been cut off.

e, Extensor radialis longior.

f, Extensor radialis brevior.

g, Part of the flexor profundus perforans

h, Supinator radii brevis.

i, Part of the adductor pollicis manus.

k, One of the three external interossei; the other two may be easily distinguished without letters.

l, Tendons of the extensors of the fingers, joining with those of the lumbricales and interossei, which form a tendinous expansion on the back of the four fingers.

N. B. On the right hand, part of the flexors of the fingers and thumb, part of the adductor pollicis, and the whole of the adductor minimi digiti, are seen.

INFERIOR EXTREMITY.

a, Glutæus minimus.

b, Obturator internus; its fleshy belly is seen within the pelvis.

Beneath *b*, the tendon of the obturator externus.

c, Semimembranosus.

d, The short head of the biceps flexor cruris.

e, Triceps magnus.

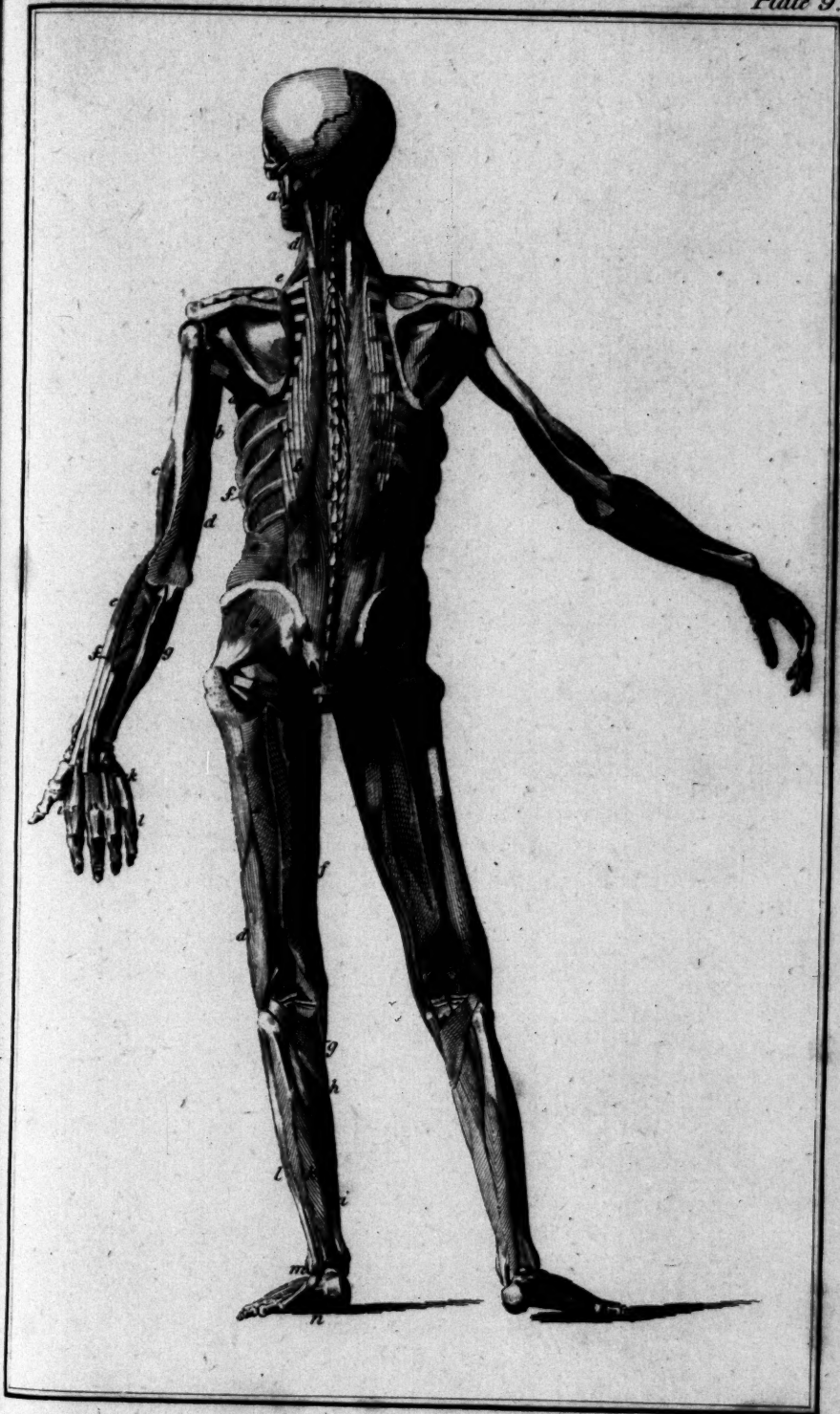
f, Gracilis.

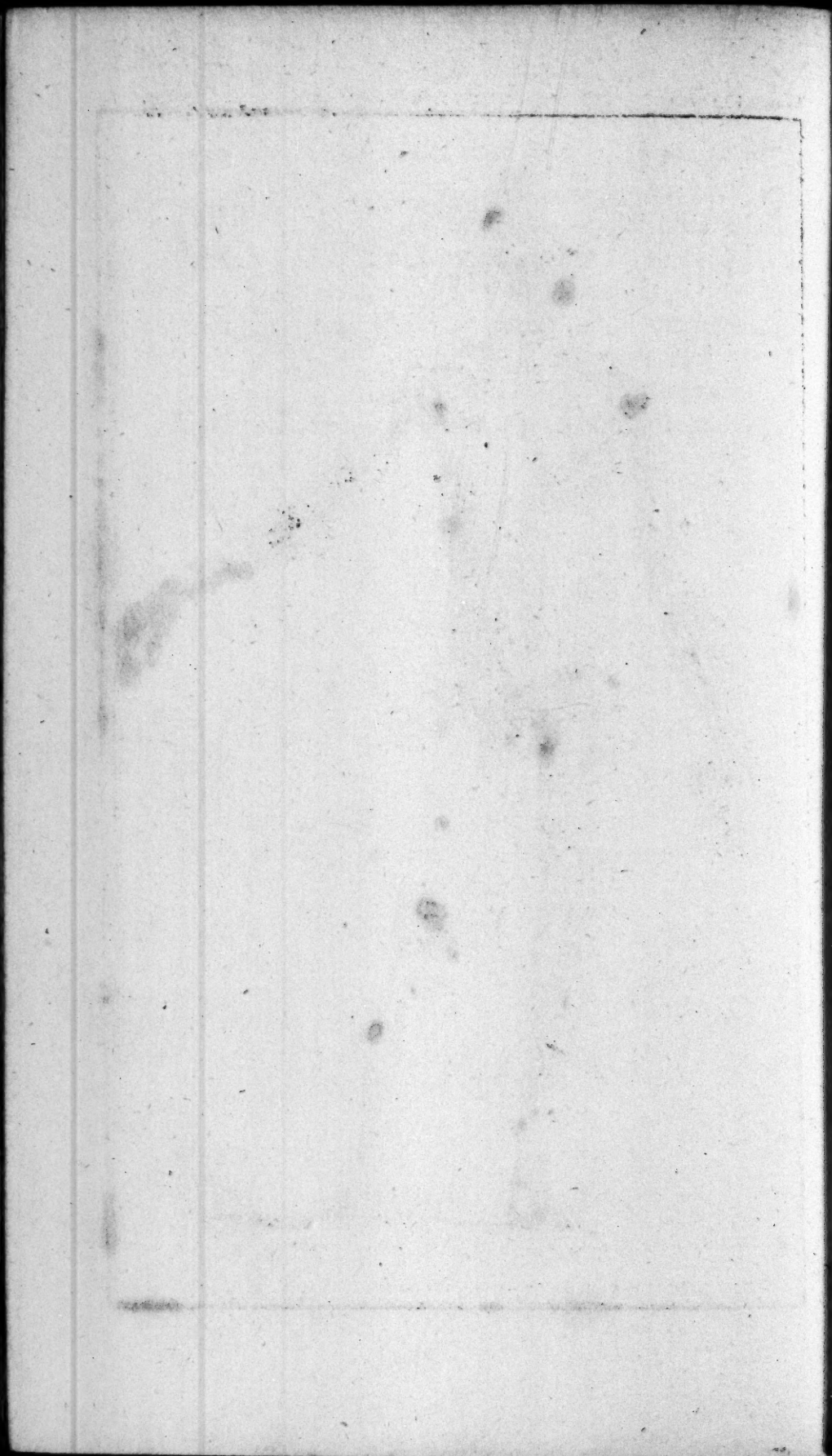
In the ham, the origins of the two heads of the gastrocnemius externus and plantaris, are seen.

g, Poplitæus.

h, Tibialis posticus.

i, Flexor





- i*, Flexor longus digitorum pedis.
- k*, Flexor pollicis longus.
- l*, Peronæus longus, running down to be inserted into the metatarsal bone of the little toe.
Beneath it, the peronæus brevis, passing to the sole of the foot.
- m*, Extensor brevis digitorum pedis.
- n*, Part of the flexor longus digitorum pedis.

C H A P. XV.

THE CELLULAR SUBSTANCE, FAT, AND INTEGUMENTS OF THE BODY.

General Description of the Cellular Substance; its Uses.—The Fat; its Uses.—The Skin.—The Organ of Touch.—The Epidermis.—Cause of the black Colour of the Africans.—Corns.—Fontana's microscopic Observations on the Epidermis.—Quantity of Perspiration from the human Body.

IN the preceding chapters the muscles of the human body have been treated of as so many distinct and separate masses of flesh. It is necessary, however, to remark, that when the anatomist comes to trace them in the subject, he finds the case far otherwise, as most neighbouring muscles are mixed and confused together by an intertexture of fibres, as well as by being involved in cellular substance.

The cellular substance is a loose fibrous web, and when filled with air plainly exhibits its real structure, viz. that of cells communicating with each other.

This substance forms a great part of the body, as it is interposed between all the muscles, all the fasciculi of muscular fibres, and it should seem also, that it involves the ultimate fibres, of which these fasciculi are composed.

All the blood-vessels also, and nerves, are in their course attached to the neighbouring parts by means of this substance. Many of the glands too, which are composed of smaller masses, are united into one
body

body by its intervention. It seems probable, indeed, that the membranes which invest the contents of the abdomen and thorax, and other membranes in other parts of the body, are composed of the cellular substance in a more consolidated state; and it is therefore very properly considered as an universal connecting medium in every part of the body.

The uses of this substance are so important, that, in all probability, animals could not exist without it. By uniting the fibres of the muscles into compact masses, it secures them from becoming entangled with each other, and with the minute blood vessels, lymphatics, and nerves, which are every where distributed among them. At the same time, however, that it connects together the muscles, and preserves them in their relative situations, it is sufficiently loose to give full play to all their motions. It serves also the purpose of a soft and compressible cushion, interposed among the muscles, and, being always moist and slippery, renders their motions easy, and prevents friction.

The cellular substance also affords a lodgment to the fat, and, together with it, fills up the interstices between muscles, and adds to the beauty, evenness, smoothness, and softness of the surface of the body.

The Abbè Fontana, on examining the fat of different animals, found it fluid and of an oily nature. It was contained in very minute vesicles heaped together, and these vesicles were covered with a thin tissue of twisting fibres. On pressing them, he

plainly perceived the fat ooze out on all sides, but on the most careful examination was unable to discover any ducts going to or from them.

The uses of the fat, as has been already intimated, are in some respects similar to those of the cellular substance, in which it is seated. It involves many of the viscera, particularly those of the abdomen, and here it increases, in people disposed to obesity, to a great degree. Within the cranium, where by its pressure it might injure the brain, none of this substance is found.

The cellular substance, besides serving the purposes already mentioned, by being placed between the skin and the muscles, is always considered as one of the integuments of the body. The other integuments are the skin, properly so called, and the epidermis or scarf skin.

The skin is probably nothing more than a condensed cellular substance, copiously furnished with blood-vessels, lymphatics, and nerves, as it within gradually becomes less dense, and is at length insensibly lost in the loose cellular substance. It covers the whole surface of the body, is tough, elastic, and forms, by means of the nerves, which terminate in it, particularly at the extremities of the fingers, where it is most sensible, the organ of touch.

The cutis, when freed from the epidermis, which is its external covering, is found to be furnished with innumerable papillæ, which appear like minute granulations; their use is probably to increase the sensibility of the skin, as where it is most sensible they are most remarkable.

The

The skin or cutis, however, not only covers the outer parts of the body, but becoming thinner and more delicate enters and invests internally the various cavities which open on the surface. It is every where pierced with blood-vessels, and in some parts with the ducts of small glands, which are seated between the skin and the cellular substance, and which pour out an oily sebaceous matter for the lubrication of the surface of the body.

The epidermis or scarf skin every where covers the true skin, which would otherwise, from its extreme sensibility, occasion much uneasiness from the friction to which the surface of the body is necessarily exposed. The epidermis consists of a mucous substance, which is placed next the true skin, and a dry, transparent, and in some measure horny substance, which is placed outwards.

The mucous substance, called corpus mucosum, or rete Malpighianum, is of a consistence between that of a solid and a fluid, and is often treated of by anatomists as a distinct covering of the body. The colour of it varies according to the complexion. In fair people it is white, in brown people of a dusky hue, and in the Africans black. In the latter it is also more solid, and can be separated from the external part of the epidermis, which cannot be effected in Europeans. By friction, the epidermis gains very much in thickness, as may be observed in the hands of labouring people, and in the soles of the feet of those much accustomed to walking. Corns, which are nothing but hardened epidermis,

are the consequence of the pressure and friction of tight shoes *.

The epidermis is not furnished either with nerves or blood-vessels, and is therefore insensible. The Abbè Fontana submitted some very minute portions of the epidermis, taken from his hand, to examination by a microscope which magnified seven hundred diameters. The epidermis appeared to be composed of winding cylinders, which approached each other, and retreated with much regularity and order; small globules also were in parts perceptible. When the portion of epidermis was covered with water, it appeared more transparent, and the cylinders and globules were seen more distinctly. He could observe nothing, however, like perforations or holes in the epidermis, and therefore doubts of their existence. It seems probable, the Abbè Fontana adds, that the lymphatics, which le Pere della Torre pretends to have seen in the epidermis, were nothing but these winding cylinders.

We must believe, however, from the quantity of sensible and insensible perspiration, especially in warm climates, where, according to Sanctorius, who made his experiments in Italy, it amounts to five eighths of the food taken in, that there are perforations in the epidermis for the passage of exhalant arteries. It may be also added, that the appearances exhibited

* The cure of these disagreeable excrescences is very obvious from this account; nothing is indeed required for this purpose, but to cover them with any soft adhesive substance, which will protect them from friction, when they will naturally decay, and in time come off spontaneously.

by objects submitted to microscopes of high powers are never much to be depended on, and have given rise to numerous deceptions.

Immediately below the skin of quadrupeds, except those of the porcine (swine) species, lies a thin fleshy expansion, called *panniculus carnosus*, covering the greater part of the body, and surrounding the other muscles. In man there is nothing similar to this, excepting the *platysma myoides*, or the occipito-frontalis muscle. The use of this thin muscular expansion is to wrinkle and move the skin in order to shake off dust, insects, &c.

CHAP. XVI.

THE HAIR AND THE NAILS.

Opinions of Anatomists with respect to the Nature of the Hair, Nails, &c.—Hair originates from the Cellular Substance.—Fontana's Observations on Hair.—The Nails.—The Horns, Hoofs, and Claws of Animals.

MANY anatomists chuse to call the hair, the nails, and the horns of animals, productions of the epidermis; by Malpighi and Rush the hairs were supposed to be continuations from the nerves; neither of which opinions, however, seems to be sufficiently proved, though the former appears by far the more probable. The hairs are distributed more or less remarkably over the whole body except on the palms of the hands and soles of the feet. They rise each of them from a separate oval bulb placed beneath the true skin, and lodged in the cellular substance, and they are surrounded by a sheath, which rises with them as far as the surface of the body.

The Abbè Fontana took a hair, which he cleansed by repeatedly drawing it through a piece of fine linen dipt in water; he examined it with lenses of different powers, from some which magnified 400, to others which magnified 700 diameters, and the appearances, he informs us, were uniformly the same. The hair in general appeared of the colour of transparent amber; towards the center, however, of it, there was an obscure line, which was broken
at

at one part. It appeared woven, and formed by, or covered with, twisting cylinders, interrupted at places, and winding like the intestines of animals. Among the winding cylinders there appeared minute globules of the same diameter with the cylinders. Having crushed the hair at one of its extremities, it appeared as if formed of many irregular polished trunks, which were composed of bundles of very small winding cylinders, with some globules scattered on the cylinders themselves.

The nails are horny insensible bodies, formed of thin lamellæ or plates. They rise by a square origin from the last joints of the fingers and toes, and are hard where they are exposed to the air, but soft near their roots. The structure of the horns, hoofs, and claws of animals is very similar to that of our nails. A minute portion of a finger nail being submitted to the microscope, exhibited the same appearances as the epidermis. Both the nails and hair grow entirely from below, by a regular propulsion from their roots.

CHAP. XVII.

THE CAVITY OF THE ABDOMEN.

*Contents of the Abdomen.—Parts involved by the Peritoneum.—
Parts not involved by it.—The Peritoneum.—The Mesentery.—
The Omentum.—Different in Man and Quadrupeds.*

THIS cavity is bounded above by the diaphragm, below by the bones of the pelvis, at the sides by various muscles and the false ribs, before by the muscles of the abdomen, and behind by the vertebræ of the loins and the os sacrum. Strictly speaking, however, no part is said to be within the cavity of the abdomen, which is not involved in a thin transparent membrane, called the peritoneum, of which a more particular description will presently be submitted to the reader.

The parts which are involved in the peritoneum are, the mesentery, the omentum or caul, the stomach, the small and great intestines, the lacteal vessels, the pancreas, the spleen, and the liver.

The organs which are not involved in the peritoneum, but are placed behind it, are the kidneys, the ureters, the receptacle of the chyle, the aorta, and the vena cava.

The upper part of the bladder is involved in the peritoneum, the lower is placed without it.

The peritoneum is to be considered as a membrane forming an internal covering to the parts which are the boundaries of the abdomen, and at the same time doubled back on itself in such a man-

ner

ner as to form the external covering of the abdominal viscera.

The internal surface of the peritoneum is smooth, its external is rough, and united to the neighbouring muscles and vessels by the intervention of cellular substance. The cellular texture attached to the peritoneum, and in some parts included within its duplicatures, is generally replete with fat. The peritoneum is a dense but thin and transparent membrane, the uses of which are to retain the viscera of the abdomen in their places, and by the smooth and moist covering which it affords them, to prevent adhesions of one viscus to another; for which it is excellently adapted by being continually moistened by a serous fluid, which proceeds from very minute pores. The existence of these is proved by spreading a portion of the peritoneum on the end of the finger, and then pulling it very tight on all sides; by these means the pores are dilated, and small drops may be observed to proceed from them.

The mesentery is a production of the peritoneum, and is formed by two laminæ of this membrane including cellular substance. It rises by a narrow origin from the first, second, and third vertebræ of the loins; it advances forwards, and gradually becomes broader in its progress. The mesentery at length embraces the intestines with its laminæ, and thus affords them the coat which they derive from the peritoneum. That part of the mesentery which involves the small intestines is more properly called the mesentery; that which involves the large is distinguished by the term mesocolon. The mesentery includes between its laminæ all the blood-

vessels and nerves which belong to the intestines, and also the numerous lacteal vessels which take up the chyle from the intestines, and the glands with which these vessels are connected.

The omentum or caul is also formed by a duplication of the peritoneum, including thin cellular substance, with a large quantity of fat. It is variously attached to several of the viscera of the abdomen. The superior portion of it is divided into two borders, one of which is fixed to the arch of the colon, the other along the great curvature of the stomach. Below this it is loose, and is placed between the intestines and the anterior part of the peritoneum. Besides this large membranous covering, called the great omentum, there is a much smaller membrane of the same kind, which is called the little omentum. It is fixed by its whole circumference partly to the small curvature of the stomach, and partly to the concave side of the liver. The little omentum is thinner and more transparent than the other, but its structure is much the same, and it is in fact a continuation of the larger.

The omentum in man descends as far as the navel, in quadrupeds much lower. The reason for this difference seems to be, that from the erect posture of man, the oily matter exuded from the omentum must fall downwards to lubricate the intestines, which are placed still lower; this, however, cannot happen in quadrupeds, which have the trunk of the body in a horizontal situation, and therefore stand in need of a longer omentum; but as the use of the omentum is not fully ascertained, this explanation is perhaps imaginary.

CHAP. XVIII.

THE STOMACH AND INTESTINES.

General Description of the Stomach.—Length of the Intestines in Man and Quadrupeds.—Small and large Intestines.

THE stomach is a membranous sack, in form, when distended, not unlike a bag-pipe. The stomach is much larger towards the left side than towards the right. It has two orifices, one towards its left side, where the œsophagus or gullet enters, called the cardia, and another towards the right, called the pylorus, which opens into the intestines. The great extremity of the stomach is in the left hypochondrium, and for the most part immediately under the diaphragm, yet the left orifice is not in the left hypochondrium, but almost opposite to, and very near the middle of the bodies of the lowest vertebræ of the back. The small extremity of the stomach does not reach to the right hypochondrium; it bends obliquely backward towards the other orifice; so that the pylorus lies about two fingers breadth from the body of the vertebræ, immediately under the small portion of the liver, and consequently lower down and more forward than the cardia. The stomach is connected to the omentum, and by means of the omentum, on the left side, to the spleen.

The

The orifices of the stomach are placed in the recesses on each side of the spine, and the body of the stomach is closely applied to it, and in a manner bent round it. The orifices of the stomach are therefore placed further back than its body, and are also a little higher, though when the stomach is distended its body rises nearly to a level with its orifices. The body of the stomach is distinguished into two curvatures; the concave surface, which is applied round the spine, is called the lesser curvature, and that which is convex, and is turned forwards and downwards, the greater.

The stomach is formed of four coats. The external of these is the peritoneal; the second is muscular, and is formed of fibres, which are continued from the muscular coat of the œsophagus. These fibres are variously distributed in the stomach. Some run directly in the lesser curvature to the right orifice of the stomach, and are lost in the duodenum; some run down each side of the stomach, and are lost in its widest part towards the left side. Besides these longitudinal fibres, the stomach is surrounded by some which are circular, and which are also continued from the œsophagus. There is a large assemblage of muscular fibres round the right orifice of the stomach, which constricts it so as to prevent the food from passing into the intestines before it has undergone the proper changes in the stomach.

If we examine the inner surface of the small extremity of the stomach, where it ends in the intestinal canal, we observe a circular border with a roundish hole in the middle, which is the pylorus,

as

as before mentioned. The border is formed, partly by a fold of the internal coats of the stomach, and partly by a collection of fleshy fibres fixed in the duplicature of the tunica cellulosa, and distinguished from the other muscular fibres by a thin whitish circle, which appears even through the external coat, round the union of the stomach and intestines.

The third coat of the stomach, which constitutes the greatest part of its substance, is the cellular, or, as it has been improperly called, nervous coat. This is thick, firm, of a white colour, and is connected to the muscular by the intervention of cellular substance, as it is also to the coat within.

The fourth and inner coat of the stomach is the villous. This and the cellular coat, being more extensive than the rest, are formed into numerous wrinkles or folds. It obtains the name of *villous* from the unevenness of its surface, as being similar to wool or hair when immersed in water. It is single, of a red colour, and is copiously supplied with mucus.

The stomach is furnished with lacteals, which rise most numerously from it near its right orifice; it is also very copiously furnished with nerves and blood-vessels, which will be more fully described hereafter. With respect to the uses of the stomach, they will be spoken of at large in the chapter on digestion.

By the intestines is meant the whole of the alimentary tube beyond the stomach. They are divided into the small and the large. The small intestines are sub-divided into the duodenum, the jejunum, and the ileum. The large into the cœcum, the

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the colon, and the rectum. All the intestines, except some part of the duodenum, are surrounded and supported by the mesentery. In man, the length of the intestines is about six times that of the body, but in graminivorous quadrupeds their length, in proportion to that of the body, is much greater.

The small intestines fill the middle and fore-parts of the abdomen, while the large fill the upper and under parts, as well as the sides of that cavity.

The small intestines, in general, are of a cylindrical form. They are composed of four coats, the structure of which is similar, and which bear the same names as those of the stomach. The muscular coat, however, differs from that of the stomach in one respect, that the longitudinal fibres are here less numerous, and the circular fibres much more so. The same fibre, however, does not wholly surround the intestine, as the circle is made of several imperfect arches. The cellular coat is exactly the same as that of the stomach. It affords strength to the intestines, and conducts nerves and blood-vessels to and from the villous coat. The villous coat of the small intestines is exceedingly extensive, and forms, together with the cellular substance, which connects it to the cellular coat, a vast number of red semilunar folds or wrinkles, which serve to increase remarkably the internal surface of the intestines, and of course to expose the chyle more fully to the mouths of the lacteals.

The small intestines assist in the preparation of the chyle, and propel their contents towards the great intestines.

With respect to the small intestines in particular, several circumstances are to be noticed. The duodenum, so named from its being about twelve inches in length, differs from the others in not being entirely surrounded by the peritoneal coat; its muscular coat, however, is stronger than that of the other small intestines, and its colour is more florid. The duodenum, beginning from the stomach, first runs towards the right side downwards, and rather backwards; then it bends towards the right kidney, to which it is slightly connected, and thence passes before the renal artery and vein, ascending gradually from right to left, till it gets before the aorta and last vertebra of the back. It continues its course obliquely forwards by a gentle turn, and then terminates in the jejunum. Through this whole course the duodenum is firmly bound down and concealed by the folds of the peritoneum. The duodenum is more lax, and of larger diameter than the other small intestines, and by its various risings and fallings is calculated to retain the food for some time before it passes into the jejunum. About six inches from the pylorus, the common bile duct and the duct from the pancreas pour their contents together into the duodenum.

Of the remaining part of the small intestines, two fifths are called the jejunum, and the remaining three fifths the ileum, as no other characteristic mark of distinction can be pointed out. The upper part of the small intestines is indeed uniformly more red, rather wider, and its structure more robust than the lower part, but the gradation is regular. Nothing particular is to be observed at any part, which can furnish a just foundation for a
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change of name, and Haller accordingly comprehended the jejunum and ileum under the term of *intestinum tenue*, or small intestine. The jejunum is placed more about the umbilical region, the ileum more in the hypogastric. The small intestines at length terminate in the large, in the hollow of the right iliac bone, below the kidney. At this place there is a valve, which exhibits the appearance of a slit or chink. This valve permits a free passage from the small intestines to the large, but prevents any thing from passing readily from the large to the small.

The cœcum, which forms the beginning of the great intestines, may be considered as a production of the colon expanded into a bag. It is about four fingers in length and as many in breadth. It is situated in the right iliac region, and rests on the broad part of the os ileum. At its lower part it has a long small process, called the vermiform, from its resemblance to an earth worm. This process is plentifully furnished with mucus, which it pours into the cœcum. In apes this process is wanting, but its place is supplied by a gland, which affords a slippery fluid. In some birds we meet with two vermiform processes, and in some kinds of fish they are very numerous. Under the name of colon is comprehended almost the whole of the great intestines. The colon begins in the right iliac region, and is attached to the kidney, thence it rises as high as the stomach and the liver. It now runs transversely before the stomach to the left side, is connected to the spleen and kidney, descends into the left iliac region, and being there bent in the form
of

of the letter S, it terminates in the rectum. The structure of the colon is similar to that of the small intestines. It is more robust, however, and the longitudinal muscular fibres, which are mixed with ligamentous substance, are united into three fasciculi, giving it in some measure a triangular form. These fasciculi are continued from the vermiform process of the cæcum to the end of the colon, where they gradually disappear.

Along the whole course of the colon are a number of cells formed by circular contractions of the intestine, which serve to retard the progress of its contents.

Along the whole course of the large intestines we also observe small projections of a fat substance, contained in elongations of their common coat. They seem in their nature very analogous to the omentum, and are considered by Winslow as a kind of small omenta; they are accordingly named appendices epiploicæ.

The rectum, which is a continuation of the colon, begins at the lowest vertebræ of the loins. It is bent like the internal surface of the os sacrum and os coccygis, to which it is closely applied, and terminates at the anus. The blood-vessels of the intestines will be mentioned in treating of the general distribution of the arteries and veins.

C H A P. XIX.

THE LIVER, SPLEEN, AND PANCREAS.

Nature and Situation of the Liver.—The Gall Bladder.—Bile Ducts.—Cause of Jaundice.—The Spleen.—The Pancreas.—Its Uses.

THE liver is an organ of a deep red colour, and is by far the largest gland in the body. It is situated immediately beneath the diaphragm. In man, the liver is divided into two portions or lobes, the larger of which is placed in the right hypochondrium, and the smaller extends across the epigastric region, towards the left. The liver is divided on the upper and anterior side into its lobes by a broad ligament, on the lower and posterior, by a deep fissure.

The upper surface of the liver is convex and smooth, corresponding to the concavity of the diaphragm. The lower surface is concave and uneven. The anterior and inferior margin of the liver is acute, the posterior and superior obtuse. At the back part of the liver, near the great fissure, there is a triangular eminence, called the small lobe of the liver, or lobulus Spigelii. The ligaments of the liver, by which it is supported, are four. Of these, one supports either lobe, and the broad ligament supports the middle. These ligaments are productions of the peritoneum, and are very different from what are called by the same name in other parts of the body. They pass

pass from the diaphragm to the liver. Besides these, there is the round ligament, which is formed by the concretion of a considerable blood-vessel of the foetus, and passes from the liver to the navel. Besides being supported by these ligaments, the great lobe of the liver is likewise connected by immediate adhesion, without the intervention of the peritoneum, to the tendinous part of the diaphragm. Round this adhesion we may observe the peritoneum folded back, to form the external covering of the liver.

The blood-vessels of the liver, which will be hereafter particularly considered, all enter on the concave side of this organ, where it is divided into its two lobes. The uses of the liver are to secrete and prepare the bile.

The gall-bladder is a membranous receptacle, sufficiently large to contain two or three ounces of bile. It is connected to the inferior part of the right lobe of the liver in such a manner, that its fundus or bottom is placed forwards, and is in contact with the colon, and its neck is placed backwards. In shape the gall-bladder much resembles a pear. It consists of four coats, which are very similar to those of the intestines, and are called by the same names. The gall-bladder, as well as the liver, and the other viscera of the abdomen are covered by the peritoneum.

The ducts, which serve to convey the bile formed in the liver to the duodenum, deserve particular attention. The duct which comes from the liver, and is called the hepatic duct, is constituted of a number of smaller ducts, which rise through the whole substance of the liver. This duct is joined

to another coming from the gall-bladder, and these ducts together constitute the common bile duct. The common duct descends towards the pancreas, and passing behind the duodenum, pierces its external coat. After having run between the coats of this intestine for some distance, it is at length, between its second and third coat, united with the duct from the pancreas, and the fluids from the liver and pancreas being thus mixed, are poured together into the cavity of the duodenum.

The gall-bladder in man receives all its contents by means of the communication between the cystic and hepatic ducts. In some animals, however, the gall-bladder receives its bile by peculiar ducts immediately from the liver, and in these animals the cystic and hepatic ducts do not unite. From the structure and connection of these ducts in man it is evident, that all the bile which passes into the duodenum must pass through the hepatic and common bile ducts, and that which goes to the gall-bladder passes through the cystic duct. The ducts are furnished with a muscular coat. The use of the gall-bladder seems to be to retain the bile till its more watery parts being removed, the remainder may become thicker, more pungent, and more acrid. It is so placed that it may be pressed upon by the distended stomach, and its contents therefore discharged when they are most required to assist in the process of digestion. The gall-bladder is also emptied by the compression and agitation of the viscera, which happen in vomiting. The bile in the gall-bladder sometimes concretes into hard masses called gall-stones. As long as these

these remain in the gall-bladder they occasion little or no inconvenience, but when they are propelled into the ducts they distend and irritate them so as, when of a large size, to be productive of very violent pain. When these concretions are stopped in the common gall duct, they prevent the passage of bile into the intestines. The bile, not escaping in the usual manner, is accumulated in the liver, and being taken up by the absorbents is carried in the circulating system, and produces jaundice.

The spleen is a spongy viscus, of a colour between deep red and blue. Its figure is so irregular as to admit of no description; it is somewhat oblong, however, but is convex on the side which is applied to the ribs, and concave on that which is turned inwards towards the other viscera of the abdomen, and where it receives its blood-vessels. It is placed on the left side, in the left hypochondrium, and is opposite to the two last of the false ribs.

The spleen is connected to the stomach by blood-vessels and a ligament, to the omentum, to the left kidney, to the posterior part of the diaphragm by the peritoneum, to the pancreas by vessels, and to the colon by a ligament. The spleen has only one coat, which can be distinctly perceived, and which is derived from the peritoneum. The spleen is extremely vascular, and when macerated seems wholly constituted of numerous blood-vessels. It has no excretory duct, and it is remarkable, that though an organ of such considerable size, its use is entirely unknown.

The pancreas is a glandular organ, of a pale-red colour, and is called in certain animals the sweetbread. The pancreas is situated in the epigastric region, behind the stomach, in the triangular space surrounded by the windings of the duodenum. In form it resembles the tongue of a dog, the narrow termination of which is placed towards the spleen, and is connected to that organ by blood-vessels. The pancreas in the human subject is eight or nine inches in length but very narrow, and its situation in the body is very nearly transverse. The liquor prepared by this gland is remarkably similar to those prepared by the glands which furnish saliva to the mouth; so that the pancreas may be considered as the largest salivary gland in the body. Like the salivary glands, the pancreas is a conglomerate gland, or consists of a number of small glandular masses united by cellular substance. Near the pancreas is observed a smaller gland of the same kind. This is called the little pancreas, and pours its contents into the pancreatic duct. We have already seen, that where the pancreatic duct pours its contents into the duodenum, it is united with the common bile duct.

C H A P. XX.

THE ORGANS PLACED NEAR, BUT WITHOUT
THE CAVITY OF THE ABDOMEN.

The Glandulæ Suprarenales.—The Kidneys.—The Bladder.

THE glandulæ suprarenales are two triangular bodies, the fabric of which is analogous to that of glands. In the fœtus they are larger than the kidneys themselves, over which they are placed; but in adults they are much smaller. They are hollow, and are filled with a reddish matter. The right suprarenal gland is fixed to the liver, the left to the spleen and pancreas, both to the diaphragm, and each of them to the kidney, above which it is placed. They are furnished with no excretory duct, and their use is unknown.

The kidneys are two organs of a pale red colour, and a firm consistence, in form resembling the beans which bear the same name. They are placed without the cavity of the abdomen, on each side of the spine, and extend across the two lowest false ribs as far as the bottom of the second lumbar vertebra; they rest on the great psoas muscle, the square muscle of the loins, and the transverse of the abdomen, in such a manner that the right kidney is placed below the liver and the colon, somewhat lower and further back, the left under the spleen, the stomach, the pancreas, and the colon, somewhat higher and more forwards. The length of the kidneys is about six inches, their breadth about four. Of the two margins of the kidneys, that which is placed outwards

is convex, that placed inwards concave. The kidneys are variously connected to the viscera, which are next them. The right kidney is connected to the colon which, as should have been before remarked, is here partly without the cavity of the abdomen.

The kidney is made up of three different substances; first, an external part of a pale colour, which chiefly consists of numerous convolutions of blood-vessels, and is called the cortical part. The other two substances, that is the medullary or striated, and the papillary, are really but one and the same mass, of a redder colour. The radiated striæ are continued into the papillary portion, where they terminate in about eleven or twelve papillæ, corresponding with the number of glandular portions, of which the kidney was originally composed. At the point of each papilla we see with the naked eye, in a slight depression, several small holes, through which the urine may be perceived to flow when the kidney is compressed. Each papilla lies in a kind of membranous calix or sheath, which opens into a common cavity, called the pelvis. The pelvis is also membranous, being a continuation of the calix. In man the cavity of the pelvis is not uniform, but distinguished into three portions, each of which contains a certain number of calices, together with the papillæ which they surround. The kidneys are surrounded with a strong firm membrane, which is very closely applied about them. This, however, does not proceed from the peritoneum, but is connected to the posterior part of that membrane by means of a large quantity

tity of cellular substance, which is always plentifully filled with fat.

The urine, which is secreted in the kidney, drops from the papillæ into the pelvis. All the subdivisions of this bag ultimately terminate in a membranous canal, called the ureter, which, descending between the peritoneum and the great psoas muscle, reaches the urinary bladder, to which it conveys the urine. The ureters of both kidneys enter the bladder at the posterior part, near the neck, which is the most fixed point. They run some distance between the coats of the bladder, before they open into its cavity, and this structure has the effect of a valve, in preventing the fluid when the bladder is very full, from returning towards the kidney.

The ureters are about a span long, and their canal is much wider in some parts than in others. They are in general about the size of a writing pen, and are somewhat curved in their course from the kidney to the bladder, so as to resemble the letter *s*. They are furnished with several coats, one of which is muscular. They are very sensible, as is proved by the acute pain which persons who are subject to the gravel experience while the stones are passing through them.

The urinary bladder is a membranous sack of considerable size. It is placed at the anterior part of the pelvis; when it is empty, it sinks below the upper part of the ossa pubis, but when filled, rises considerably above them. It is larger in women than in men. The upper part of the bladder is called its fundus, which is much wider than where it terminates in its neck. The anterior part of the
bladder,

bladder, which is placed next the ossa pubis, is more flat, that turned backwards more convex. Its general form is a round oblong.

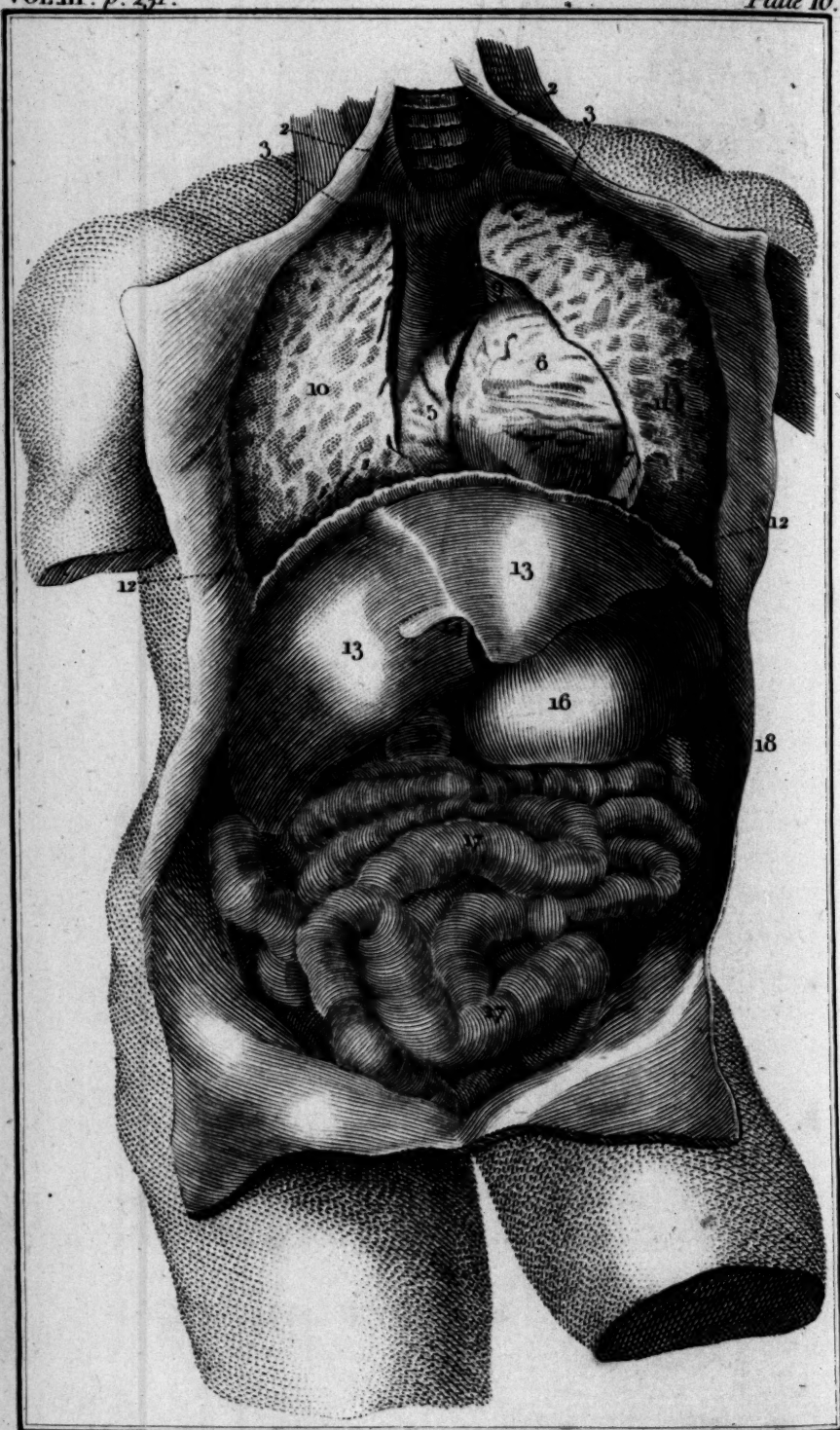
The bladder in men is connected behind to the rectum, and before it is always attached by cellular substance to the ossa pubis. It is also connected to the navel by ligaments, which are the remains of two arteries of the foetus, and as its fundus projects into the cavity of the abdomen, the bladder is also connected to the peritoneum, which covers part of its fundus.

The coats of the bladder are, first, a coat of cellular substance, by which it is connected to the neighbouring parts; 2dly, a muscular coat, the fibres of which, beginning from the neck, ascend on both sides towards the fundus. At the neck the fibres cross each other, and in this manner form a sphincter, by which animals are enabled to retain the urine; and yet a continuation of the same fibres towards the fundus assists in expelling it. In this part, as well as in the tongue and mouth, we have an instance of the different parts of the same muscular fibres counteracting each other.

The third coat of the bladder is like the nervous coat of the intestines, and bears the same name. The inner coat has many foldings, and is plentifully supplied with mucus. The fundus of the bladder also derives a coat from the peritoneum. The uses of the bladder are to receive the urine, to retain it for a time, and to expel it through the urethra from the body.

Had the peritoneum been spread over the bladder in its whole extent, the weight of the viscera in our erect

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erect posture would have so borne upon it, that a considerable quantity of water could not have been collected there. The peritoneum, however, by passing from the sides of the abdomen over the superior part of the bladder, forms a support for the incumbent viscera, and preserves a certain space below, where they cannot press. In the quadruped, where, from the horizontal position of the body, the abdominal viscera do not press on the bladder, that organ is entirely invested with the peritoneum.

The figure in plate X. represents,

1. The trachea.
2. The internal jugular vein.
3. The subclavian vein.
4. The vena cava descendens.
5. The right auricle of the heart.
6. The right ventricle, the pericardium being removed.
7. Part of the left ventricle.
8. The aorta ascendens.
9. The arteria pulmonalis.
10. The right lobe of the lungs, part of which is cut off to shew the great blood vessels.
11. The left lobe of the lungs.
12. The diaphragm.
13. The liver.
14. The ligamentum rotundum.
15. The bottom of the gall-bladder projecting beyond the anterior edge of the great lobe of the liver.
16. The stomach, pressed by the liver towards the left side.

17. The

17. The small intestines.

18. The spleen.

The figure in plate XI. represents,

1. The under side of the liver.

2. The ligamentum rotundum.

3. The gall-bladder.

4. The pancreas.

5. The spleen.

6. The kidney.

7. The aorta descendens.

8. The vena cava ascendens.

9. The emulgent vein.

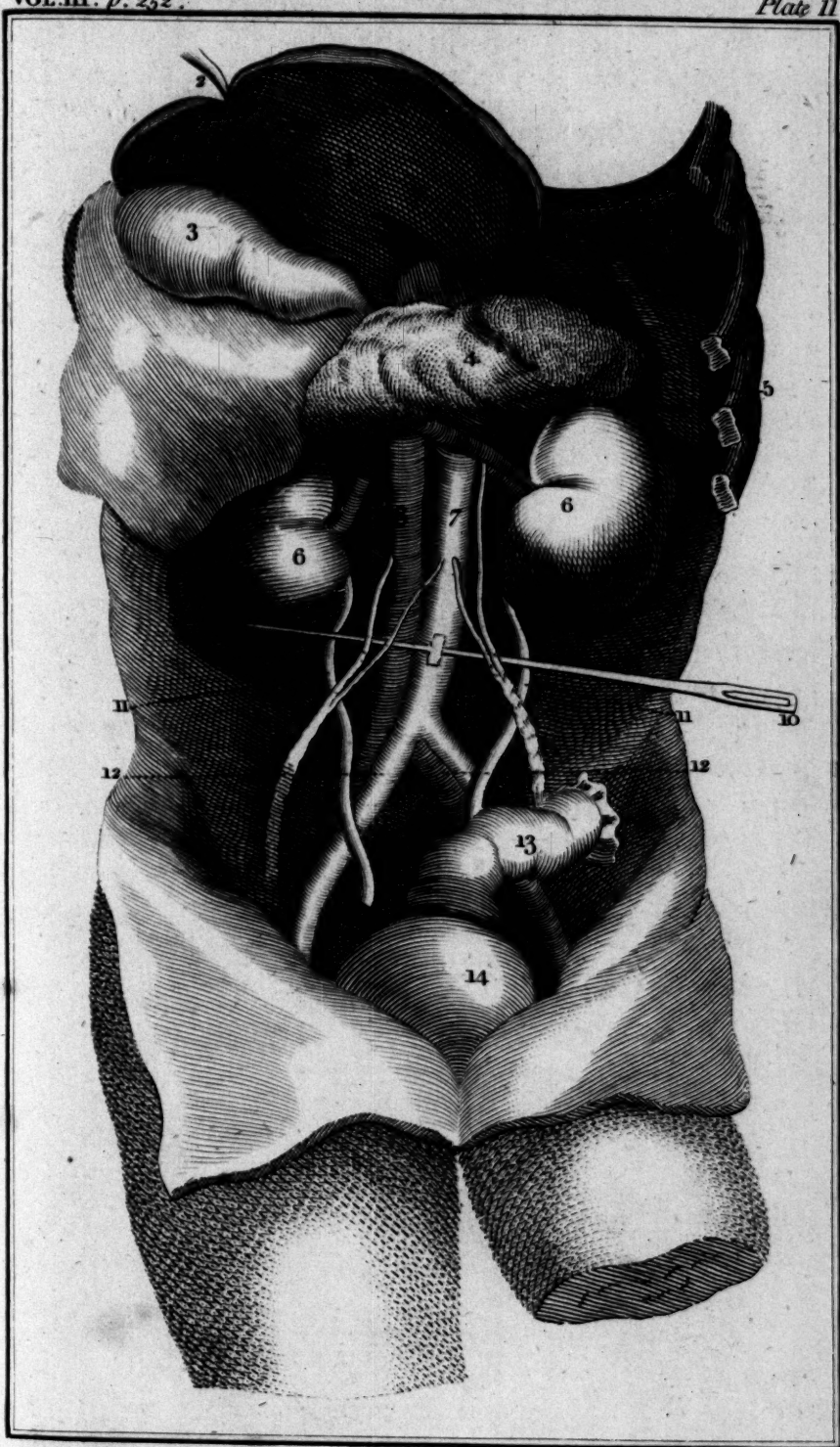
10. A probe under the spermatic vessels and the arteria mesenterica inferior, and over the ureters.

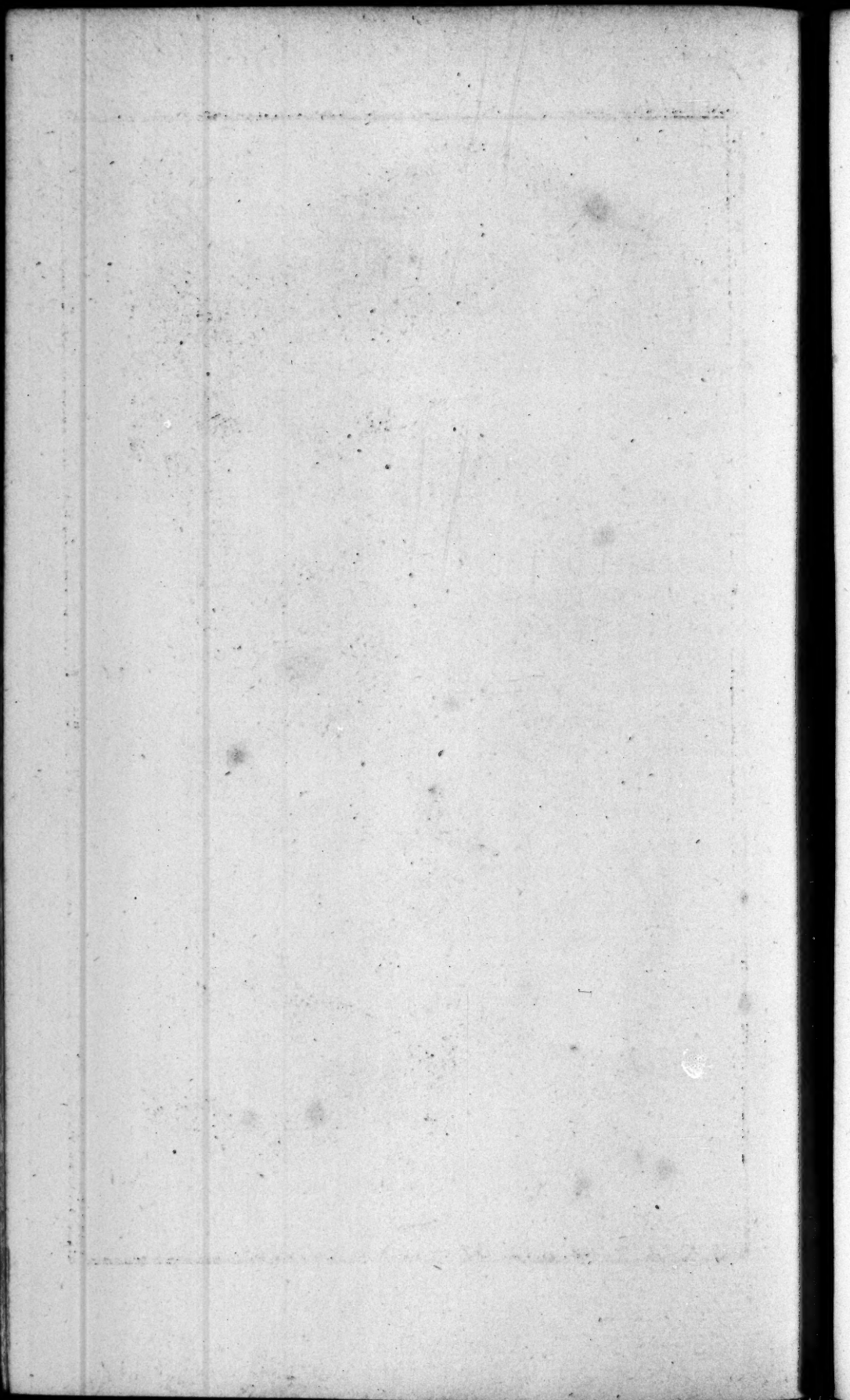
11. The ureter.

12. The iliac vessels.

13. The intestinum rectum.

14. The urinary bladder.





C H A P. XXI.

THE CAVITIES OF THE MOUTH AND FAUCES, &c.

*The Palate.—The Pharynx.—The Oesophagus.—The Larynx.—
The Glottis.—The Epiglottis.—The Wind Pipe.*

IT is unnecessary to enumerate the parts which externally limit the cavity of the mouth, as the lips, cheeks, &c. since they are obvious to common observation. Within the mouth are the bony processes which include the teeth; and which are covered by the gums. The upper and arched part of the mouth is called the palate. The palate is divided into the hard and the soft. The hard palate is bounded by the teeth, and is formed by the two ossa maxillaria and two ossa palati covered with the periosteum and the common coat of the inside of the mouth, which produces, particularly in some animals, a number of hard ridges. The soft palate or velum pendulum palatinum is a septum, which arises from the external margin of the palate bones, and laterally from a process of the sphenoid bones. It is a moveable soft substance, hanging between the cavity of the mouth and the posterior termination of the nostrils.

The soft palate is composed of the common membrane of the mouth and nose, and includes a number of mucous glands, and some muscular substance. It forms two arches on each side, descending from the hard palate. The two anterior
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of these arches are smaller and thinner, and are inserted laterally into the tongue; the two posterior are large, and are connected behind to the pharynx. In the middle and upper part, where all the half arches unite, they are lengthened into a small pointed body, which is easily seen at the back part of the mouth, and is called the columella or uvula. On each side, in the bottom of the space which is left between the anterior and posterior arches, is placed an oblong glandular body, which opens into the throat by eleven or twelve excretory ducts, and is called the amygdala or tonsil. We have the power of stopping the passage of air from the nose, by drawing up the soft palate, so as to cover its posterior openings. The whole cavity of the mouth is moistened by mucus, and the liquor from the salivary glands.

The glands which furnish the mouth with spittle or saliva are the two parotids, which are seated immediately below the ears; the maxillary, which are seated at the inside of the angles of the lower jaw; the sublingual, which are placed between the bone of the lower jaw and the tongue; and lastly, a number of small glands, placed in bunches about the opening of the ducts, which come from the parotid glands. The structure of the salivary glands is like that of the pancreas.

I shall defer the description of the tongue till I come to treat of the sense of tasting. The nose, the ear, and the eye, will be described when I treat of the senses to which they are subservient.

The cavity behind the palatum molle or soft palate is called the pharynx. At the back part it is bounded by the vertebræ of the neck, above by the

the basis of the cranium, before and laterally by the soft palate and much cellular substance, and every way by the muscles which surround the neck. The nostrils terminate at their posterior opening in the cavity of the pharynx, as do laterally the two eustachian tubes from the internal part of the ear.

The pharynx is a muscular bag shaped like a funnel, beginning from the basis of the cranium and terminating below in the œsophagus or gullet. Its substance is merely muscular, covered with the same tender and glandular membrane which lines the mouth, fauces, and œsophagus. The use of the pharynx is to receive the aliment and impel it into the œsophagus.

The œsophagus or gullet is a membranous tube, beginning from the narrow termination of the pharynx. It is placed between the vertebræ of the neck and the windpipe, and descending lower is embraced by the pleura, and lies in a triangular space behind the mediastinum. Having arrived at the bottom of the thorax it passes through the left perforation of the diaphragm, and terminates in the cardia, or left orifice of the stomach.

The œsophagus has four coats. First, a covering from the pleura; secondly, a muscular coat of considerable power; thirdly, a cellular coat; and lastly, a tender internal coat, like that of the fauces, and which is copiously supplied with mucus. The œsophagus conveys the food to the stomach.

The larynx is a hollow tube composed of cartilages, muscles, and ligaments, situated behind and below the tongue, at the anterior part of the neck.

The larynx is connected above to the os hyoides, behind to the root of the tongue and the pharynx.

The cartilages of the larynx are the cricoid or annular, which is narrow before and broad behind, and is there divided into two excavations, which receive the arytenoid or pyramidal cartilages: The cricoid cartilage forms the basis of the whole larynx. It is connected below to the windpipe, and above to the pyramidal and thyroid cartilages.

The thyroid cartilage rests perpendicularly on the cricoid, and constitutes the upper, anterior, and largest part of the larynx. It consists of two almost quadrangular plates of cartilage, which unite before at an obtuse angle, but behind are separate. This cartilage is harder and more prominent in men than in women, and has therefore been called the pomum Adami. At its posterior part the thyroid cartilage has processes above and below. The upper are united by means of ligaments with the processes of the os hyoides. The lower, which are shorter, are connected to the cricoid cartilage. The two arytenoid cartilages are the smallest which contribute to form the larynx. They are equal in size, and when joined together resemble the spout of an ewer. They are placed perpendicularly in two excavations of the cricoid cartilage at its posterior part. The glottis is formed of two ligaments, in the following manner:

Anteriorly the basis of each arytenoid cartilage is fixed to one end of a ligamentary cord, which, by its other end, is inserted about the middle of the concave side of the anterior portion of the thyroid.

At

At the latter insertion the two ligaments touch each other; but a small space is left between them, where they are connected with the arytenoid cartilages. This chink is what is called the *rima glottidis*, which is capable of contraction and dilatation.

Under these ligaments are two smaller, which also arise from the arytenoid cartilages, and, running forwards, are attached to the middle part of the thyroid cartilage. Between these superior and inferior ligaments there is on each side a small bag or cavity, called the *ventriculus Galeni*.

Over the opening of the larynx, the *rima glottidis*, is placed a cartilaginous substance, called the *epiglottis*; it is situated above the anterior or convex portion of the *cartilago thyroides*, and its lower extremity is connected by a short, broad, and very strong ligament, to the middle notch in the upper edge of that cartilage. The *epiglottis* is somewhat concave behind and convex before. Its shape resembles that of the tongue, and its termination or apex is always free, so as by its own elasticity to be naturally elevated. In deglutition, however, when the tongue is drawn backwards, the *epiglottis* is exactly applied over the *rima glottidis*, so as to prevent the food from passing into the larynx, or, as is commonly said, going the wrong way.

* The pharynx is every where connected by muscular fibres to the larynx, and the larynx is in a manner suspended in its cavity. At the anterior part of the larynx is placed a gland of considerable size, called the thyroid gland. It is not discovered to have any excretory duct, and its use is unknown.

The muscles which regulate the motions of the glottis, which is the principal organ of the voice, are the following four pairs, and one single muscle:

The crico-arytænoideus posticus arises from the cricoid cartilage, and is inserted into the posterior part of the base of the arytenoid cartilage. By its contraction it opens the rima glottidis a little, and by pulling back the arytenoid cartilage, renders the ligament tense.

The crico-arytænoideus lateralis proceeds from the cricoid cartilage laterally, where it is covered by part of the thyroid, and is inserted into the base of the arytenoid cartilage. Its effect is to open the rima glottidis, by separating the arytenoid cartilages, and consequently the ligaments which are fixed to them.

The thyreo-arytænoideus arises from the thyroid cartilage, runs backwards along the side of the glottis, and is inserted into the arytenoid cartilages. Its effect is to bring the thyroid and arytenoid cartilages nearer to each other, and consequently to relax the ligaments which are placed between them.

The arytænoideus obliquus arises from the base of one arytenoid cartilage, and crossing its fellow, is inserted into the tip of the other. When both act, they pull the arytenoid cartilages towards each other, and therefore contract the rima glottidis.

The single muscle which was mentioned is the arytænoideus transversus. It arises from the side of one arytenoid cartilage and passes to the other. It shuts the rima glottidis by bringing the arytenoid cartilages with the ligaments nearer each other.

§

Besides

Besides these, there are a few separate muscular fibres, which from their connections are called

The thyreo-epiglottideus, which arises from the thyroid cartilage, and is inserted into the epiglottis laterally. It draws the epiglottis obliquely downwards.

The aryteno-epiglottideus, which arises from the side and upper part of the arytenoid cartilage, and is inserted with the former into the epiglottis; it pulls down the epiglottis, and counteracts the effect of its elasticity.

The aspera arteria, or windpipe, is a tube formed of annular cartilages, membranes, and muscular fibres. It begins from the annular cartilage of the larynx, descends rather towards the right side of the spine into the cavity of the thorax, and is divided, into two great branches, which being afterwards subdivided, obtain the name of bronchia, and are distributed through the substance of the lungs. The aspera arteria is furnished with two membranes, the outer of which is formed of cellular substance and the inner is very soft and tender; between these membranes are placed the cartilaginous rings. These rings are connected to each other by ligamentous fibres above and below. They do not form complete circles, but are imperfect behind, where the circle is completed by a soft but strong glandular and muscular membrane. The cartilaginous rings are thin and elastic, but thicker and broader before than at their sides. They are largest at the upper part of the windpipe, and are found to be smaller as we advance lower. Of the muscular fibres situated between the cartilaginous rings, some

are circular, which render the windpipe narrower, and others longitudinal, which render it shorter.

The windpipe in the upper part of the cavity of the thorax is divided as was before stated into two great branches, the larger and shorter of which goes to the right lobe of the lungs, the smaller and longer to the left.

The structure of the branches of the windpipe, till they enter the substance of the lungs, is the same as that of the windpipe; after they enter the lungs, however, the cartilaginous rings soon disappear, and nothing but a thin elastic coat remains. The ultimate divisions of the windpipe terminate in the air-vessels of the lungs.

C H A P. XXII.

THE PLEURA, THE LUNGS, AND THE THYMUS.

Description of the Thorax.—The Pleura.—The Breasts.—Breasts of Infants contain Milk.—The Mediastinum.—The Lungs.—The Thymus.

THE thorax is that part of the body which lies between the neck and the diaphragm. It is surrounded by the spine, the ribs, the sternum, and the diaphragm, and also, internally, by a thin membrane like the peritoneum, which forms two separate cavities, and is called the pleura. On the external part of the thorax are placed the mammæ or breasts; within is the heart, with its large vessels, and the lungs.

The mammæ, or breasts, in men, and children of both sexes, are no more than cutaneous tubercles, with a brownish circle in the middle, called the areola. In women they are two convex firm bodies, of a glandular nature. In the middle of each breast is a prominent spongy substance, called the papilla, perforated by a number of ducts for the discharge of the milk, around which is placed the areola. The internal part of the breast chiefly consists of a large quantity of fat; but there is also a large glandular substance, composed of many smaller glands, connected together by cellular membrane; this is the organ which secretes the milk, and to which the term mamma is more strictly applicable. It is re-

markable, that a small quantity of milk may in general be pressed from the breasts of new-born infants, both male and female.

The pleura, as has been intimated, is a transparent and dense membrane, continued through the left perforation of the diaphragm from the peritoneum. It covers the internal surface of the bones of the thorax and the upper part of the diaphragm, and involves the viscera of the thorax in the same manner as below it involved those of the abdomen. The internal surface of the pleura is constantly moistened, and rendered slippery by a serous exudation.

The mediastinum is formed by two laminæ of the pleura including cellular substance. These are closely connected near the sternum and vertebræ; but in the middle and towards the lower part they are separated by the pericardium and heart. Before the heart, from the pericardium to the sternum, the two laminæ adhere very closely: higher up they are divided to receive the thymus. The mediastinum divides the thorax perpendicularly into two separate cavities or sacks, which contain the lungs. The mediastinum is attached in such a manner to the anterior part of the bones of the thorax, as to render the right sack of the pleura larger than the left. Behind, the mediastinum is attached to the dorsal vertebræ, before to the sternum, below to the diaphragm and pericardium, and above to large blood-vessels.

Behind, towards the vertebræ of the back, is left a triangular space, in which is placed the windpipe, the œsophagus, the thoracic duct, and several large blood-vessels; before, the gland called the thymus occupies

occupies a similar space. The uses of the pleura are to furnish an internal covering to the bones of the thorax and the diaphragm, and an external covering to the thoracic viscera.

The union of the two sacks of the pleura, forming the mediastinum, is of use, by supporting the lungs, and by preventing their pressure on each other when the body is turned to either side. By the two sides of the thorax being thus separated, one may be wounded without impeding the functions of the other.

The lungs fill the two sacks of the pleura, one of which is placed on each side of the mediastinum. With respect to the form of the lungs, their bases are broad, and their summits form an obtuse cone. Their anterior surfaces, and those applied to the mediastinum, are flat, that next the ribs is somewhat convex, and that behind round. The lower part of the left lung is excavated to make room for the heart. The colour of the lungs is in infants reddish, in adults greyish, and in old age they verge towards dark blue or black; their surface is usually mottled.

The lungs are connected above to the neck by means of the windpipe, and below by blood-vessels to the heart. They have no other covering but the pleura, connected to them by the intervention of thin cellular substance, which in this part is always free from fat.

With respect to the structure of the lungs, the right, which is larger, consists of three lobes, the left only of two; all of these are sub-divided into a number of smaller lobes called lobules. These

divisions are connected to each other by the intervention of cellular substance. The substance of the lungs is ultimately made up of minute vesicles, called the air vessels of the lungs, which are the terminations of the windpipe.

These vesicles have extremely thin coats, and on these coats are distributed the minute ramifications of the blood-vessels which go to the lungs. It has been computed, from the extreme minuteness of the air-vessels, that the internal surface of the lungs is not less extensive than the floor of a moderate sized sitting room. These air-vessels communicate with each other through the whole substance of each lung, so that by inflating one lobule the air passes into the rest. The uses of the lungs are of the most important nature, and will be considered in a separate chapter on the subject of respiration.

The thymus, the situation of which has been just mentioned, is soft, and of a spongy texture. It is very large in the foetus, and is filled with a white thin liquor; in adults it is hard, small, and gradually decays. It is not discovered to have any excretory duct, and its use is unknown.

CHAP. XXIII.

THE HEART.

*The Pericardium.—The Heart.—The Ventricles and Auricles.—
Their Uses.—General View of the Blood-vessels.*

THE heart is a hollow muscle, included in a membranous bag, called the pericardium.

This membrane incloses not only the heart, but the great vessels which arise from it. This covering of the heart consists of three laminæ; the external of these is formed by a duplicature of the mediastinum. The middle lamina, which is the thickest and strongest, is composed of very fine tendinous fibres, which at the lower part are connected and mixed with those of the diaphragm. The internal lamina seems to be a continuation of the outer coat of the heart and great vessels. Within the pericardium is found a quantity of transparent liquor, which facilitates the motions of the heart, by preventing friction.

The heart is placed in man almost transversely, and rests on the diaphragm at the anterior part of the thorax. The basis or broad part of the heart is directed towards the right side, its point or apex towards the left, and this latter is so placed, as when the heart beats to strike the sixth rib. The upper surface of the heart is convex; the lower, which rests on the diaphragm, is flat. The greater part of the heart lies in the left cavity of the thorax.

The

The substance of the heart is muscular, and is composed of fibres, which, arising from the basis, where it is tendinous, take a winding course towards its apex in various directions.

The principal part of the muscular substance of the heart forms two cavities called the ventricles. The posterior or left ventricle of these is much thicker, stronger, longer, and rounder than the other; the anterior or right ventricle is wider, shorter, and thinner*. The septum, or that portion of muscular substance which is placed between the ventricles, seems chiefly to belong to the former, and gives the latter an appearance of being merely an appendage.

At the basis of the heart are two cavities, which are each of them divided by anatomists into two parts, the sinus and the auricle; but as these together form one cavity, it will answer best the purpose of perspicuity to speak of them simply by the name of auricles. The auricles are composed of two membranes, with some muscular fibres. Like the ventricles, they are separated from each other by a septum, and one of them obtains the appellation of the anterior or right auricle, the other that of the posterior or left. Each of them communicates with the ventricle, which is placed next it, and which bears the same name.

Between the auricles and ventricles of the heart are placed valves, as also at the mouths of the great

* The terms anterior and posterior auricles and ventricles of the heart are used as descriptive of the situation of them in man. In quadrupeds, the anterior auricle and ventricle, or those which perform the same purpose, are placed towards the right side, and the posterior towards the left.

arteries, which prevent the blood from passing in any other than the proper direction.

The valves, which are placed between each of the auricles and ventricles, are turned inwards towards the latter cavities. The valves, situated at the entrance of the anterior ventricle, have three remarkable points, and are therefore called *valvulæ tricuspides*; those of the posterior ventricle terminate in two points, and from being compared to a mitre, are called *valvulæ mitrales*. In each of the great arteries, which proceed from the ventricles, the aorta and pulmonary artery, are seated three valves turned from the ventricles, and called *semilunares*. All these valves are elongations of the internal membrane of the part to which they belong. They are closely connected on that side from which the current of blood proceeds, and their other extremity is loose. When the blood, therefore, proceeds in its proper course, they are pressed close to the side of the vessel, and occasion no impediment; but when it is about to return in the contrary direction, they are raised from the side of the vessel, and meeting in the middle of its cavity, shut up the channel. The internal surface of the ventricles is extremely uneven, from a number of fleshy columns which rise from its inside, and some of which terminate by tendinous extremities in the valves of the heart, which they support, and enable to perform their office more effectually.

Besides the connection, however, between the auricles and ventricles of the heart, each auricle communicates with a large vein, and each ventricle with a large artery. The use of the auricle
is

is to receive the blood from the vein, and to discharge it into the cavity of the ventricle. The ventricle receives the blood from the auricle, and drives it forcibly into the artery. By a repetition of those actions is performed the circulation of the blood, which is the subject of a separate chapter, in which I shall take occasion to mention some remarkable varieties in the hearts of different races of animals.

The vessels of the human body are either blood-vessels or lymphatics.

The blood-vessels are membranous tubes, which convey the blood to and from the various parts of the body. They are divided into arteries and veins. The arteries pulsate, and convey the blood from the heart; the veins return it towards the heart, and do not pulsate*. The large trunks, both of the arteries and veins, are near the heart; at a distance from it they are divided into numerous small branches in a manner very similar to that in which the trunk of a tree is lost in its branches and twigs.

The arteries are formed by the following tunics. The first is derived from the cavity, through which the artery passes; in the thorax, from the pleura; in the abdomen, from the peritoneum, &c. The second is a loose covering of cellular substance, which contains smaller vessels, for the nourishment of that on which they run, and which in the large arteries often contains a considerable quantity of fat.

* As a pulse is only to be perceived in the arteries, this circumstance will enable the most unskilful to distinguish the nature of any blood-vessel.

The third is muscular, and is composed of several small arches of muscular fibres, many of which go to the formation of a circle. Within this is a thin cellular coat, which adheres closely to the former; and lastly, there is a firm, smooth, and whitish coat, with which the circulating mass of fluids is in contact.

The structure of the veins is the same as that of the arteries, but more delicate. The muscular coat is in them so thin, or of so pale a colour, as not to admit of demonstration in man, but is plainly seen in a vessel called the vena portarum of the ox. That veins, however, have muscular coats in all animals, is inferred from their contractile power.

The venous system is far more capacious than the arterious.

Arteries are commonly said to diminish in size, as they recede from the heart; but this is not the real state of the case. As long as an artery continues undivided, its diameter remains the same; and when it does divide, the area of the vessels formed by this division is always greater than the area of the artery from which they are produced; so that the artery may in truth be said to be increased. This rule holds equally with respect to the division of the great trunks of arteries, and the sub-divisions of their branches. The trunks also of veins are always smaller than the sum of the smaller veins from which they are formed.

The larger trunks of blood-vessels are separate tubes, but their branches form various communications with each other, and these communications
increase

increase as the vessels become more minute, so as at length to form a web of vessels in the parts on which they are distributed. The advantages of this structure are very obvious, as by a communication of vessels each part may receive blood from many sources, and no part therefore suffers by the division of the blood-vessel which more particularly belongs to it; its advantages are like those of commerce among mankind, by which the effects of partial losses are guarded against by a mutual exchange of conveniencies.

The branches of arteries are in general sent off at much more acute angles than those of the veins, by which the passage of the blood through the arteries is the less impeded.

The arteries have in general a corresponding vein placed near them; but to this rule there are several exceptions, which will be more particularly noticed in speaking of the venous system. The trunks of the veins, and almost all the arteries, are deeply seated; but the smaller veins are every where thickly distributed on the surface of the body, immediately below the skin. By this structure a passage is provided for the blood on the surface of the body, where the internal veins are so compressed by the action of muscles as not easily to transmit their contents. The external and internal veins communicate very freely.

CHAP. XXIV.

GENERAL DISTRIBUTION OF THE ARTERIES.

The Aorta.—The coronary Artery.—The carotid and subclavian Arteries.—The intercostal Arteries.—Bronchial Arteries.—The Cæliac Artery.—Mesenteric Arteries.—Renal Arteries.—Lumbar Arteries.—Iliac Arteries.—Crural Artery.—Pulmonary Artery, &c.

FROM the posterior, inferior, or left ventricle of the heart proceeds the principal artery of the body, called the aorta. Immediately on leaving the heart it sends off two small arteries, called the coronary, which are distributed on the heart itself. The aorta now rises three or four inches above the heart, when it is turned backwards and towards the left side, forming an arch over the left division of the windpipe. From the convex side of its arch, the aorta sends off three large arteries, which go to the head and arms. The first of these is equal to the two other in size, and soon divides into two branches; of these one is the right carotid artery, which is distributed on the right side of the head; the other is the right subclavian, which proceeds to the right arm. The arteries which belong to the left side of the head and left arm arise separately from the aorta, and are the two other branches which were mentioned as being sent off from its arch.

Upon

Upon measuring the sides of the vessels, the surface of the united trunk of the right subclavian and carotid is less than that of the left subclavian and carotid, which arise separately; if so, the resistance to the blood must be less in that common trunk than in the left subclavian and carotid. The resistance being smaller, the impetus and velocity of the blood must be less affected; and as the strength of the muscles is as the quantity of blood sent into them in a given time, those of the right arm will be stronger than those of the left. This therefore accounts in some measure for the preference which is generally given to the right arm, though it must be acknowledged that it is difficult, from this reasoning, to account for the preference which some children give to the left. The right subclavian and carotid sometimes arise separately like the left, but it has not been ascertained that this exception to the usual structure happens more frequently in left than in right handed persons. In quadrupeds we observe something of the same preference of the right limbs, and attended with the same distribution of the arteries. In birds, which must be nicely balanced, the arteries of both sides come off alike.

The two carotid arteries proceed upwards on each side of the windpipe, behind the sterno-cleido-mastoideus muscle, and the platysma myoides, as high as the larynx, without a division. About this part the carotid artery is divided into two others, called external and internal carotid arteries. The external carotid supplies the parts about the larynx, the face, the external parts of the head and the

dura mater. The other division of the carotid is distributed almost entirely on the brain, and is therefore called the internal carotid artery. It first proceeds to the lower orifice of the great canal of the pars petrosus of the temporal bone. After being contorted according to the course of this passage, it at length enters the cavity of the cranium, at the side of the sella turcica. As it leaves the bony canal, it sends off an artery, which supplies the contents of the orbit, and which communicates with twigs of the external carotid about the face.

The internal carotid afterwards runs under the basis of the brain at each side of the infundibulum, where it is at a small distance from the carotid artery of the other side. At this part it commonly divides into two branches, one of which passes towards the anterior, the other towards the posterior part of the brain, where it communicates with the vertebral artery of the same side. The arteries of the brain are inclosed in the folds of the pia mater, and are not distributed on the substance of the brain itself, till after having undergone minute division.

The subclavian arteries are so called, because they pass under or behind the clavicles. Each subclavian artery sends off a considerable one to the internal parts of the head. They proceed from the upper and posterior part of the subclavian, and obtain the denomination of vertebral arteries, because they pass through openings in the transverse processes of the vertebræ of the neck. Having reached the great foramen of the os occipitis, they enter the cranium, and pierce the dura mater. The two vertebral arteries, after they have entered the cra-

nium, gradually advance towards each other, and at length unite, forming the *arteria basilaris*.

The subclavian artery also sends off twigs to the mediastinum, thymus, trachea, and pericardium. It also sends off two branches of a larger size, called the *mammaria interna*, and *cervicalis*, besides the *vertebralis*, which has been already described.

The subclavian artery, where it leaves the thorax, immediately above the first rib, changes its name to that of the *arteria axillaris*, because it passes under the axilla. In this course it gives off four principal branches, the *thoracica superior*, *mammaria externa*, *thoracica humeralis*, and *axillaris scapularis*, which are distributed on the parts from which they derive their names. The *arteria axillaris*, where it passes behind the tendon of the *pectoralis major*, again changes its name to that of the *arteria brachialis*. Between the axilla and the middle of the arm, the artery is only covered by the common integuments; below this it passes under the biceps muscle, and runs obliquely forwards as it descends. In its course, it continues to send off branches to the adjoining parts. A little more than a finger's breadth below the bend of the arm, the *arteria brachialis* divides into two branches, called the *cubitalis* and *radialis*, the former of which lies next the ulna, the latter next the radius.

The aorta, having completed its arch, is directed downwards, being situated towards the left side of the spine. Below the fourth vertebra of the back, it obtains the name of the descending aorta, which, between this part and the diaphragm, sends off the following branches :

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Chap. 24.] *Intercostal and Bronchial Arteries, &c.* 275

The inferior intercostal arteries are generally seven or eight on each side. They arise in pairs along the posterior part of the aorta, and run transversely towards each side on the bodies of the vertebræ. They afterwards pass in the bony ridge at the inferior edge of the ribs, almost as far as the sternum, being distributed in their course on the intercostal muscles.

The bronchial arteries are two or three in number, which sometimes arise from the aorta, sometimes are branches of the superior intercostal, or of the arteries of the œsophagus. They enter with the divisions of the bronchia into the substance of the lungs, on which they are distributed.

The arteries of the œsophagus are generally two or three in number. They arise from the anterior part of the aorta and are distributed on the œsophagus.

One or more arteries are also sent to the diaphragm, and distributed on its lower surface.

Below the diaphragm, the descending aorta sends off

The cæliac artery, which arises from the anterior part of the aorta by a short trunk, which divides into three principal branches; one runs upwards, and is called the coronary artery of the stomach, and which is chiefly distributed on that organ; another runs towards the right, and having sent off one or two branches to the stomach and duodenum, joins the vena portæ, enters the fissure of the liver, and is distributed through its substance; the third

is directed to the left, under the stomach and pancreas, to the spleen. In its progress it distributes small branches to the stomach, pancreas, and omentum.

At a short distance below the cœliac, the superior mesenteric artery proceeds from the anterior part of the aorta. Near its origin it sends off a small branch, which carries blood to the large extremity of the pancreas, and the neighbouring part of the duodenum. Being included between the laminæ of the mesentery, it forms a kind of arch, which descends obliquely from left to right, and from which about sixteen or seventeen branches are sent off, most of which are spent on the small intestines. As these branches approach towards the intestines, and are more minutely divided, they inosculate and communicate very freely with each other, so as at length to surround the intestines like net work. From the concave side of the arch proceed several branches, one of which is of great length, and makes a remarkable communication with the inferior mesenteric artery. From the numerous communications among the arteries of the intestines, we may observe how carefully these parts are provided with a supply of blood.

The next arteries, which are sent off from the aorta, are the two emulgent or renal. They arise one on each side, and proceed almost horizontally to the kidneys. As the aorta lies towards the left side of the spine, the right renal artery is longer than the left. The reverse is the case with the veins,

as the vena cava is placed on the right side of the spine.

Above the renal arteries arise two arteries, which go to the glandulæ suprarenales, and which also send branches into the adipose membrane which surrounds the kidneys.

Below the renal arteries arise the two spermatic arteries, which are very small. They are placed behind the peritoneum, on the psoas muscles.

The lower mesenteric artery arises from the anterior part of the aorta, below the spermatic. It is soon divided into three or four branches, which gradually separate from each other. The superior of these branches forms the communication, which was mentioned as taking place between the two mesenteric arteries. The inferior mesenteric artery is distributed chiefly on the colon; it sends, however, a considerable branch to the rectum, called the arteria hæmorroidalis interna.

The lumbar arteries proceed in five or six pairs from the posterior part of the aorta, much in the same manner with the intercostals. The superior sometimes send blood to the diaphragm and intercostals, but they are principally spent on the psoas muscles, the quadrati lumborum, and the oblique and transverse muscles of the abdomen. One or more arteries are sent off from the lower part of the aorta, or some of the neighbouring arteries, to the os sacrum and large nerves of these parts.

Near the last lumbar vertebra, the aorta is divided into two equal trunks, called the common iliac arteries, one of which lies to the right the other to the left, and which recede from each other as they descend.

scend. About three fingers breadth from their origin, each iliac trunk is divided into two secondary arteries. One of these, which is called, from the parts on which it is distributed, the hypogastric, or internal iliac artery, is gradually bent forwards, and terminates like a ligamentous cord at the navel. The other artery is called the external iliac, and passes under the ligament of Fallopius, in its way to the lower extremity, on which it is distributed.

From the convex side of the curvature of the hypogastric artery are sent off several considerable branches, which may be distinguished by the following names; *iliaca minor*, *sacræ laterales*, *glutæa*, *sciatica*, *pudica communis*, *hæmorrhoidalis media*, *obturatrix*.

The *iliaca minor* is a small artery, which is distributed on the iliac muscles and bones. The *arteriæ sacræ laterales* are commonly two in number. They are sent to the fore part of the os sacrum, and penetrating its substance, are distributed to the nerves and membranes within. The *arteria glutæa* is of very considerable size; it passes out of the pelvis with the sciatic nerve, and is distributed on the two larger *glutæi* muscles; it also gives branches to some other neighbouring muscles, and to the parts about the anus. The *arteria sciatica* gives some branches to the os sacrum and adjoining muscles. It passes obliquely over the sciatic nerve, and goes through the great posterior sinus of the os ileum. It afterwards ascends on the outside of the os ileum, and is spent on that and the *glutæi* muscles. The *arteria pudica communis*, or *pudica interna*, divides
into

into two branches; one of these runs on the inside of the tubercle of the ischium to where the corpora cavernosa take their origin; at this place it is divided into several smaller branches, which are distributed on the corpora cavernosa, the bulb of the urethra, and the anus. The second principal branch, sometimes called the pudica externa, runs between the bladder and rectum.

The hæmorrhoidalis media proceeds from the pudica interna, or some of the other large branches; it goes to the lower part of the rectum, and sends twigs to the bladder, vesiculæ feminales, and prostate gland. The arteria obturatric perforates the obturator muscles, and is distributed to the neighbouring muscles.

The hypogastric, or internal iliac artery, having sent off all these branches to the parts about the pelvis, ascends on the side of the bladder towards the navel, where it meets its fellow of the opposite side. These arteries, near the navel, are in the adult contracted into the appearance of a ligament, and are quite closed; in the foetus, however, they are a continuation of the trunk of the hypogastric arteries by which the circulation is carried on between it and the placenta.

It has been already mentioned, that the external iliac artery passes out of the abdomen under Fallopius's ligament; it here gives off two considerable branches; one of these, the arteria epigastrica, runs upwards on the muscles at the anterior part of the abdomen, and communicates freely with the mamma interna; the other branch,

sent off from the external iliac at this place, runs to the internal edge of the os ileum, and is ramified on the oblique and transverse muscles of the abdomen, communicating with the lumbar arteries.

After it has passed under the ligament of Fallopius, the external iliac changes its name to that of the crural or femoral artery. It sends off, first, three small branches; one, the pudica externa, goes to the inguinal glands, &c. and communicates with the pudica interna; another goes to the pectineus muscle; and the third, to the upper part of the sartorius.

Afterwards the trunk of the artery descends to the head of the os femoris. About three fingers breadth from the ligament of Fallopius, it sends out three considerable branches. The external branch, called the circumflexa externa, is distributed to the muscles of the thigh, situated before and at the outside. The middle branch, named the profunda, runs down on the inside of the thigh between the triceps muscles. The internal branch, called the circumflexa interna, runs backwards towards the great trochanter, and supplies the muscles, seated at the posterior part of the os femoris, and sends a branch into the substance of the bone itself.

After having sent off these branches, the crural artery, covered by the sartorius muscle, proceeds down to the bottom of the thigh, and passes through the tendon of the adductor magnus, a little above the internal condyle of the os femoris; afterwards, continuing its course through the hollow of the ham, it is called arteria poplitea.

While

While in the ham it sends off branches, which ascend to communicate with those of the crural artery. Branches are also sent to the joint. When it has reached the back part of the head of the tibia, it gives off two branches, one to each side. As the poplitea ends, it divides into two principal branches; one of which runs between the heads of the tibia and fibula, passing from behind forwards on the interosseous ligament, where it takes the name of *arteria tibialis anterior*; the second branch divides into two others, the larger called *arteria tibialis posterior*, the other *arteria peronea posterior*.

From the anterior, superior, or right ventricle of the heart proceeds an artery (the pulmonary) nearly equal to the aorta, but the coats of which are less robust. Its trunk, having run upwards almost as high as the aorta, is divided into two parts, one of which passes under the aorta to the right lung, while the other proceeds to the left. These arteries enter the lungs with the bronchia, and the divisions and sub-divisions of both are distributed together through their substance. The ultimate ramifications of the pulmonary artery are spread out on the air-vessels, through which the blood undergoes that change from the air which it is the purpose of respiration to effect.

Besides receiving arteries in common with other parts of the body, we find that the lungs continually receive and return the same quantity of blood as passes through all the other parts of the body; from which we may form some idea of their extreme vascularity.

In the plate annexed (XII.) the arteries are represented freed from the muscular and fibrous parts.

1. Aorta ascendens.
- A. Three semilunar valves.
2. Trunk of the coronary artery.
3. Aorta descendens.
4. Subclavian artery.
- 5.5. Carotid arteries.
- 6.6. Vertebral arteries.
- 7.7. Arteries that go to the lower part of the face, tongue, &c.
- 8.8. Temporal arteries.
- 10.10. Trunks which go to the foramina narium, &c.
- 11.11. Occipital arteries.
- 12.12. Arteries which go to the fauces, &c.
- B.B. A small portion of the basis of the skull.
- 13.13. Contorsions of the carotid arteries, before they pass to the brain.
- C. The pituitary gland between the contorted trunks of
- 14.14. The carotid arteries,
- D.D. The ophthalmic arteries,
15. Contorsions of the vertebrals.
16. The vertebral arteries, where they lie on the medulla oblongata.
- 18.18. Ramifications of the arteries within the skull.
- E.E. The arteries of the cerebellum.
- 19.19. Arteries of the larynx, &c.
- 20.20. Arteries which convey blood to the muscles of the neck and scapula.

21.21. Mam-

- 21.21. Mammary arteries,
- 22.22. Arteries of the muscles of the os humeri,
 &c.
- 23.24. Divisions of the arteries of the arm.
- 25.25. A branch of an artery not found in all sub-
 jects.
- 26. External artery of the cubitus.
- 27. Arteries of the hands and fingers.
- 28.28. Division of the aorta.
- 29. Bronchial artery.
- 31. Intercostal arteries.
- 32. Coeliac artery.
- 33. Hepatic arteries.
- 34. Arteria cystica, on the gall-bladder.
- 35. Lower coronary artery of the stomach.
- 36. Pyloric artery
- 37. Epiploic artery.
- 38. Ramifications of the coronary artery, which
 embrace the bottom of the stomach.
- 39. The upper coronary artery of the stomach.
- 40.40. Phrenic arteries.
- 41. Splenic artery.
- 43. Upper mesenteric artery.
- 44. Superior branches of the mesenteric artery,
 freed from the small intestines.
- 45. Lower mesenteric artery.
- 49.49. Emulgent arteries.
- 50. Arteriæ lombares.
- 51. Spermatic arteries.
- 52. Arteria sacra.
- 53.53. Common iliac arteries.
- 54.54. Iliacus externus.
- 55.55. Iliacus internus.

56.56. Umbilical arteries.

57.57. Epigastric arteries.

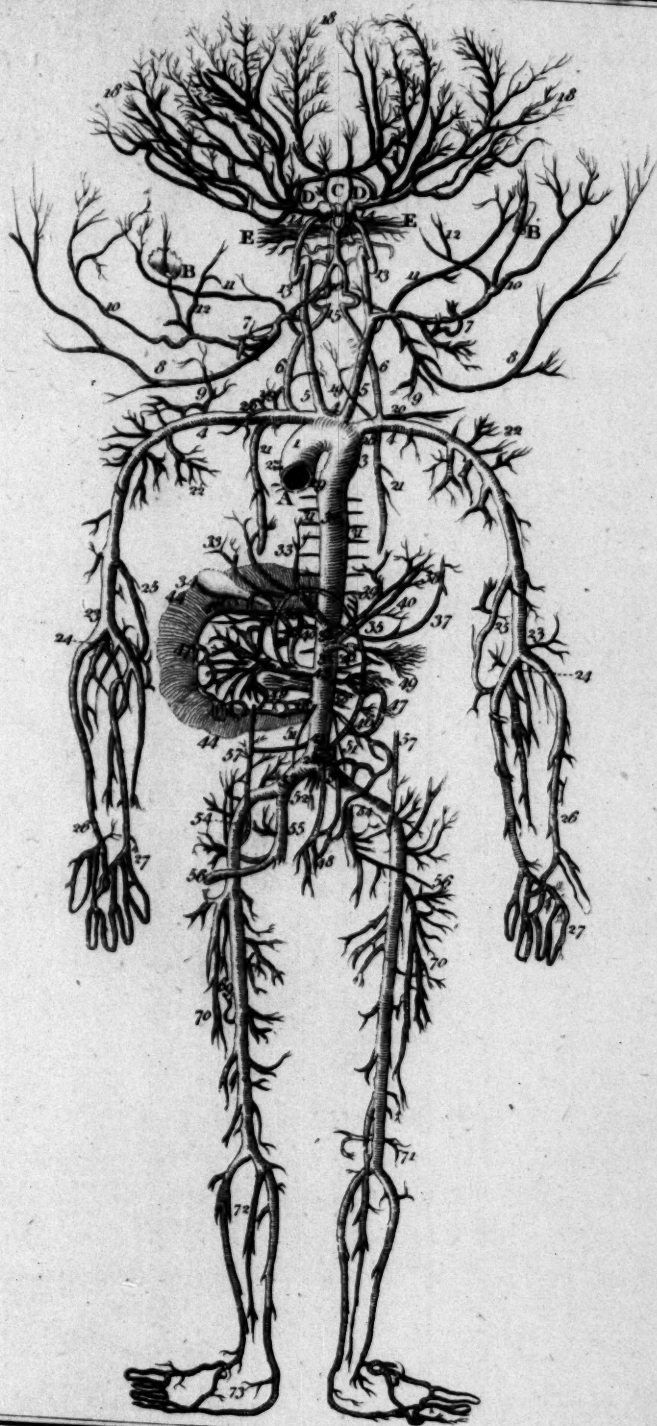
69. The crural artery.

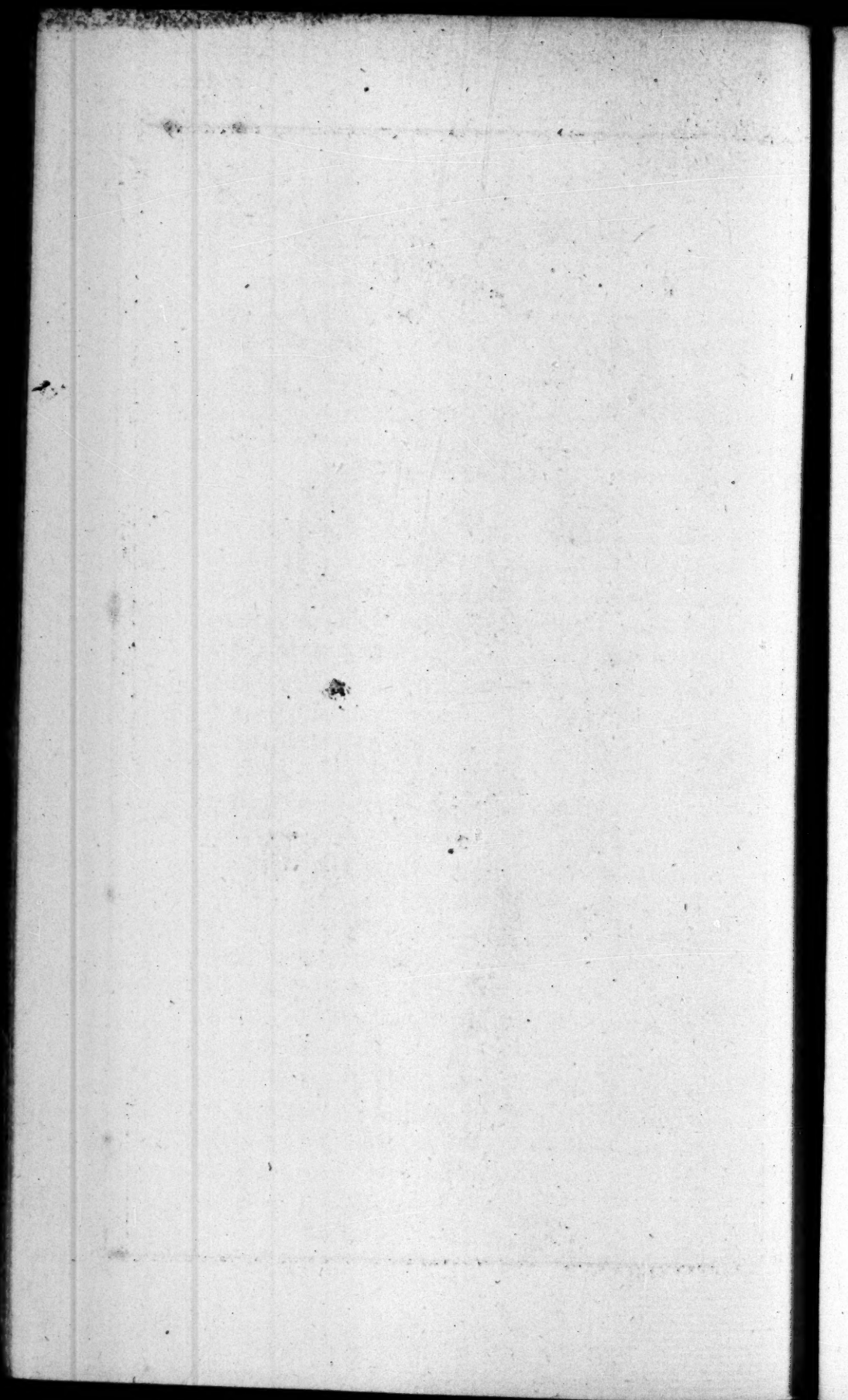
70. Arteries which pass to the muscles of the thighs and tibiæ.

71. Part of the crural artery.

72. The three large trunks of the arteries of the leg.

73. Arteries of the foot.





C H A P. XXV.

GENERAL DISTRIBUTION OF THE VEINS.

Pulmonary Veins.—Vena Cava.—Veins of the Head.—Jugular and Subclavian.—Veins of the Superior Extremity.—Vena Azygos.—Veins of the Lower Extremities.—Course of the Blood through the abdominal Viscera, the Liver, &c.

IN describing the arteries we followed the course of the blood, and beginning with the largest trunks, traced the several branches in the order in which they were sent off. In pointing out the course of the veins, however, and still following the course of their contents, the order of the description will necessarily be reversed, as it is necessary, in this case, to begin with the ramifications, and trace them into the trunks.

The veins of the body may be divided into two classes; those which return the blood conveyed by the pulmonary artery, and those which return that of the aorta.

It has been already remarked, that, besides the blood which the lungs receive in common with other parts of the body, they also receive all that is transmitted by the pulmonary artery. This, after being distributed through the substance of the lungs, is returned by veins, which at length unite into four trunks, and passing through the pericardium, are inserted into the posterior auricle of the heart.

The

The blood, which is sent to the various parts of the body by the aorta is ultimately received and returned by two large trunks, the vena cava superior and inferior, which enter the anterior auricle of the heart. I shall now proceed to enumerate, in a cursory manner, the branches by which these trunks are supplied.

The vena cava superior is formed in the following manner. In treating of the brain, I shall endeavour to describe more fully the triangular canals, called sinuses, situated in the dura mater, and which perform the office of veins. The blood, which is sent to the internal parts of the head, after passing through other veins and sinuses is received by the two lateral sinuses; these terminate in the internal jugular veins, which correspond with the internal carotid artery, and terminate in the subclavian vein. The external jugular vein, which corresponds with the external carotid artery, receives the blood from the external parts of the head, and also terminates in the subclavian vein. This vein also receives the contents of the vertebral vein, which corresponds with the artery of the same name.

The veins of the superior extremities run in two sets; some of them lie immediately under the skin, others are deeply seated, and accompany the arteries. The vena basilica is formed by a variety of branches; it proceeds immediately under the skin, along the course of the ulna, to the internal condyle of the os humeri. It afterwards runs up along the inside of the arm, communicating freely both with the deep and superficial veins. The vena cephalica receives, at the extremity of the radius, branches
which

which correspond with those of the radial artery. The trunk runs along the radius, between the muscles and integuments, communicating with all the neighbouring veins; having passed the fold of the arm, it ascends near the outer edge of the external portion of the biceps, still communicating with the other veins, and passing between the large pectoral and deltoid muscles, terminates, as well as the basilica, in the trunk of the axillary vein.

The vena axillaris, which corresponds with the artery of the same name, is formed by all the veins of the superior extremity. Above the axilla it receives branches from all the muscles situated about the scapula, and the upper part of the thorax. Where it passes between the clavicle and first rib, it changes its name from that of the axillary vein to that of the subclavian. The subclavian veins, receive the contents of the jugular and vertebral veins which come from the head, and also other branches from adjoining parts. The left subclavian vein also receives a particular vein, called the intercostalis superior, which proceeds from the upper intercostal muscles of that side. The left subclavian vein also receives the contents of the thoracic duct, which is described in another place.

The two subclavian veins are directed towards each other, and uniting in the upper part of the thorax, rather towards the right side, constitute the vena cava superior. Into the upper part of the vena cava opens a vein of considerable size, called the vena azygos, or the vein without a fellow. This arises from the lower and internal part of the thorax, and soon passes over to the right part of the spine. As it ascends along the right side of the thorax, it
receives

receives the inferior intercostal veins of that side, and higher up a trunk common to two or three veins, which also come from the intercostals. At the top of the thorax it is bent forwards over the right lung, and opens into the vena cava a little above the pericardium. The vena cava now perforates the pericardium, and descends to the anterior or right ventricle of the heart.

The veins of the lower extremities, which terminate in the vena cava inferior, are

The vena saphena major, which begins on the inside of the foot, at the great toe, and runs to the inner ankle; here it receives other branches, and then runs up the inside of the tibia, immediately under the skin. After communicating freely, and receiving other branches, the saphena passes along the inside of the knee, and afterwards along the thigh as far as the middle of the sartorius muscle; it next runs on the forepart of the thigh to the groin, and at length opens into the top of the femoral vein. As this vein is quite superficial, it may be traced through the whole of its progress, when it is distended with blood, by the naked eye.

The vena saphena minor returns the blood from the outer side of the foot; from this part it runs up on the outside of the tendo Achillis, and next between the gastrocnemius externus and the skin. It terminates in the vena poplitea a little above the ham.

The vena tibialis anterior is a trunk which accompanies the artery of the same name, and terminates in the vena poplitea.

The

The vena tibialis posterior begins from the sole of the foot by several branches. These, forming a trunk, run on the inner side of the os calcis, and behind the inner ankle. It passes up between the soleus, and tibialis posticus muscles, accompanied by the corresponding artery, and opens into the vena poplitea.

The vena peronea proceeds upwards along the inside of the fibula, almost in the same direction with the arteria peronea, and also ends in the vena poplitea.

The vena poplitea, which corresponds with the artery of the same name, is formed by the three large veins described, but seems to be a continuation of the tibialis posterior. The vena poplitea runs up immediately on the muscle of the same name. About the ham it receives a number of branches from the joint and from the neighbouring muscles. A little above the ham it receives the name of the crural vein, which takes its course upwards between the biceps and other flexors of the leg, closely accompanied by the crural artery. When it has arrived opposite the trochanter minor it receives three considerable veins, the circumflexa interna, externa, and profunda, which correspond with the arteries of the same names. About an inch below the ligament of Fallopius, it receives the vena saphena major, the course of which has already been described. About this place it also receives the venæ pudicæ externæ.

After passing under the ligament of Fallopius, and entering the pelvis, it changes its name to that of the external iliac vein. It now receives the vena epigastrica, which descends towards it at the ante-

rior part of the abdomen, and other venous branches from the adjacent parts. After having received the venous branches which correspond with the arterial branches of the external iliac artery, the external iliac vein unites with the trunk of the internal iliac, or hypogastric, vein, which returns the blood sent to the pelvis by the artery of the same name. These two venous trunks uniting, form the *vena iliaca communis*, and the *iliacæ communes* of both sides uniting, form the inferior *vena cava*. This ascends on the *vertebræ* but inclines towards the right side, whereas the *aorta* is placed towards the left. It receives the *venæ lumbares*, which enter it behind in pairs. Higher up it is joined by the emulgent veins from the kidneys, the *venæ capsulares* from the *glandulæ suprarenales*, and by the right spermatic vein. The left spermatic vein commonly goes into the emulgent vein of the same side. Opposite the liver the *vena cava* receives the blood from the diaphragm and pericardium. Hitherto, none of the veins which return the blood sent to the abdominal viscera by the *cæliac* and the two mesenteric arteries have been noticed. The course of this blood, however, deserves particular attention.

The veins of the rectum form the beginning of a vein called *vena meseraica minor*, or *vena hæmorrhoidalis interna*. This afterwards unites with a branch from the left part of the arch of the colon, and opens at length into the *vena splenica*.

The *vena splenica* returns the blood from the spleen, and in its passage also receives branches from
the

the stomach, pancreas, and omentum, and also the vena meseraica minor last described.

The vena meseraica major returns the blood of most of the branches of the arteria mesenterica superior, which are distributed on the small intestines and right portion of the colon. It also receives the vena cæcalis from the beginning of the colon, the gastro colica, partly from the stomach and partly from the colon, and some other branches from the adjoining viscera, which vary in different subjects.

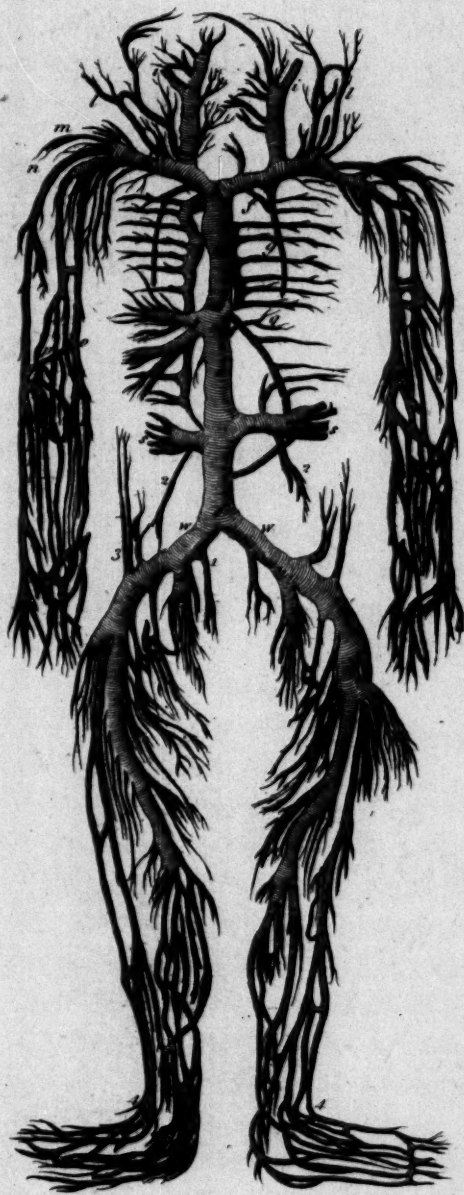
The vena splenica receives the vena meseraica minor, and the vena meseraica major the vena splenica, and thus is brought into one vessel, called the vena portæ, the blood which comes from the omentum, the pancreas, the spleen, the stomach, and the small and great intestines. The blood, however, thus collected, is not immediately returned to the heart, as in other parts of the body; for the vena portæ, having arrived at the concave part of the liver, is first divided into five branches, and these into others more minute, which are distributed through that organ like arteries, and which perform the secretion of the bile. Where the vena portæ enters the liver, its structure becomes more robust, to enable it to perform its new office. The blood, thus circulated through the liver, is again collected by another set of veins, which, uniting into two or three principal trunks, called venæ hepaticæ, pour their contents into the vena cava. The vena cava, having received these veins, perforates the diaphragm and pericardium, and meet-

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ing with the superior cava, they empty themselves together into the anterior auricle.

The veins are represented in plate XIII. though not so perfectly as I could have wished.

- a.a.* Vena cava.
- b.* Descending trunk of the cava.
- c.c.* Ascending trunk of the cava.
- d.d.* Subclavian veins.
- e.* Vena azygos.
- f.* Intercostal veins.
- g.* Mammary veins.
- i.i.* Internal jugulars.
- l.l.* External jugulars.
- m.* Right axillary vein.
- n.* Cephalic vein.
- o.* Basilic.
- q.* Phrenic.
- s.s.* Emulgents.
- w.w.* Iliac branches.
- x.* Internal iliacs.
- 1. Vena sacra.
- 2. Spermatic veins.
- 3. Epigastric.
- 4. Saphena.



CHAP. XXVI.

STRUCTURE AND COURSE OF THE
LYMPHATICS.

Two Kinds of Lymphatics.—Description of these Vessels.—Lymphatic Glands.—Lacteals.—Thoracic Duct.—Receptacle of the Chyle, &c.

LYMPHATICS are small pellucid vessels, which convey fluids perfectly, or very nearly, colourless. The lymphatics are of two kinds; those which take up fluids from the body in general, and those which receive the digested aliment from the intestines. The latter kind are called lacteals, and both of them terminate in a common trunk, the thoracic duct.

The lymphatics have at least two coats, which are thin and transparent, but tolerably strong. They have also nerves and muscular fibres, as may be collected from their sensibility when inflamed, and from their power of contraction. They are furnished with valves, which are placed in pairs, and which are so numerous, that three or four of them often occur within the distance of one inch. From this circumstance, they are frequently called valvular lymphatic vessels, to distinguish them from the minute ramifications of the sanguiferous system, which also convey a colourless fluid.

Lymphatics begin by extremely minute tubes from the whole surface of the body, from the cellular substance, from the cavities of the body, from

all the glands, from all the viscera, and in general from every part of the system.

It is now well ascertained, that not only water is absorbed by the lymphatics on the surface of the body, but many other substances. No lymphatics have been demonstrated in the brain; but from a variety of circumstances there can be very little doubt of their existence.

All the lymphatics of the body pass through certain glands, which are connected with them. When the lymphatics approach these glands, they send some branches to neighbouring lymphatics; other branches pass over the surface of the glands, and others enter their substance, in which they are so minutely divided as to escape observation. A great number of these glands are placed at the upper part of the thigh, belonging to the lymphatics of the lower extremity; others are placed under the arm, belonging to those of the upper; and there are similar glands about the neck, and in various other parts of the body. It is at present disputed among anatomists, whether lymphatic glands are formed of cells or convoluted vessels; but the latter opinion seems to be more probable. Lymphatic or conglobate glands are of various sizes, from that of a small pea to that of a bean. They are commonly somewhat flattened. In young subjects they are found of a reddish or brown colour, but they become whiter in the progress of life. Their surface is shining, which is owing to a smooth dense coat with which they are covered. These glands are said to be wanting in some animals, which yet have lymphatic vessels.

The

The lacteals are so called from a degree of whiteness in their appearance like that of milk, which they receive from the colour of the fluid which they convey. They arise from the villous coat both of the great and small intestines, but principally from the small, particularly the jejunum; passing in their course through conglobate glands, they advance between the laminæ of the mesentery towards the second or third lumbar vertebra, where they meet with the lymphatics of the lower extremities.

These are of two kinds, the superficial and deep seated. The former chiefly lie at the inside of the leg and thigh, and follow the course of the vena saphena major. In the groin they pass through lymphatic glands. Being joined by the lymphatics of the lower part of the abdomen, they pass under the ligament of Fallopius. The lymphatics of the lower extremities and pelvis, and the lacteals from the intestines, form the beginning of the thoracic duct. This vessel also receives the lymph from the other abdominal viscera.

The thoracic duct, so called from its course through the thorax, usually begins about the second or third lumbar vertebra. It is of different sizes in different subjects, and is sometimes extended at its lower part into a pyriform bag, called the receptaculum chyli; but in general there is no enlargement so remarkable as to deserve a particular name. The thoracic duct sometimes divides and again unites. At its beginning, it is situated at the right side of the aorta. It is afterwards observed in the thorax, lying between the aorta and vena azygos. It as-

cends as high as the sixth vertebra of the neck, where, forming an arch, it turns downwards and enters the left subclavian vein near the insertion of the internal jugular.

The thoracic duct is furnished with few valves, and these are placed without much regularity. At the place, however, where it is inserted into the subclavian vein, there is a circular valve, which prevents the blood from getting into it.

Besides the thoracic duct, which receives the lymph from the lower extremities and the left side, and the chyle from the intestines, there is another vessel somewhat similar, but much shorter, on the right side. This receives the lymphatics from the right arm, the right lung, and the right side of the head, and enters the right subclavian vein at the same place where the thoracic duct enters the left.

CHAP. XXVII.

OF THE BRAIN, &c.

The Dura Mater.—The Falx.—Sinuses of the Brain.—The Pia Mater.—The Cerebrum and Cerebellum.—Source of the Optic Nerves.—The Pineal Gland.—The supposed Seat of the Soul.—The Medulla Oblongata.—Source of the Nerves.—The Spinal Marrow.

THE cavity of the cranium is every way surrounded with strong bones, which have been already described. Within these, before we arrive at the substance of the brain, we meet with two membranes, called by the ancients the dura and pia mater, from an opinion that they were the source of the other membranes of the body. The same names are still applied to them by the moderns, though, as in many other cases, the reason has ceased.

The dura mater is a thick, firm, insensible membrane, extremely full of blood vessels. Its external surface performs the part of a periosteum to the internal part of the head, to which it adheres by numerous blood-vessels, particularly at the sutures, where they pass through the cranium to communicate with those of the external periosteum. Its internal surface is moistened by the exhalation of a thin fluid, which prevents its adhesion to the membrane within.

The dura mater forms several projections, which serve very important purposes. One of these, from
its

its resemblance to the blade of a scythe, is called the falx. Its narrowest end is attached to the crista galli of the ethmoid bone; it runs backwards along the course of the sagittal future, to where it meets with the lambdoidal. A little below the lambdoidal future it divides into two wings, forming a transverse septum, which is firmly attached behind to the os occipitis. The use of the falx is to divide the brain into its two hemispheres, and to support them, and prevent their pressing on each other when the head is turned to either side. The transverse septum divides the great brain or cerebrum from the smaller brain or cerebellum, the former being placed above it, the latter below. It also supports the cerebrum, and prevents it from gravitating on the cerebellum when the body is in the erect posture. The connection between the transverse septum and the falx is such, that they preserve each other in a state of tension, for if either of them is cut after the contents of the cranium are removed, the other immediately becomes relaxed and flaccid. Below the transverse septum is situated a smaller falx, which serves the same purposes in the cerebellum as the great falx does in the cerebrum. In the transverse septum is a great oval notch, through which the substance of the cerebrum and cerebellum communicate and are intimately mixed.

Both the membranes of the brain pass out of the cranium with the trunks of nerves, and afford them coverings, till they terminate in their sentient extremities.

The blood which is circulated through the brain is not returned through such veins as are found in
other

other parts of the body. We here observe a peculiar kind of canals called sinuses, which are contained in the duplicatures of the dura mater. The most remarkable of these is the longitudinal, which runs in the upper part of the falx; at the transverse septum this divides into two others, called lateral sinuses, which, passing through the basis of the cranium, terminate in the jugular veins. Near the concurrence of the superior and lateral sinuses, we observe an opening, which is the orifice of a sinus, situated along the union of the falx and transverse septum.

These sinuses are triangular veins, which, being conveyed through so firm a membrane as the dura mater, are much less liable to be ruptured or distended; these accidents are still further guarded against by certain filaments, which pass from one side of the sinuses to the other, and give still further security against the bad effects which are found to arise from the pressure of the brain. The veins, which pour their blood into the sinuses, enter them in such a manner as to produce the effect of a valve, and to prevent the blood from returning into the tender vessels of the brain, and thus over-distending them.

Besides the sinuses above-mentioned there are others of a smaller size, which answer the same important purposes. All these communicate with each other and with the great lateral sinuses, and therefore discharge their blood into the internal jugular veins.

The cavernous or lateral sinuses of the os sphenoides are reservoirs of a particular kind, containing

ing considerable vessels and nerves ; and likewise a cavernous and spongy structure, which for some unknown purpose is constantly filled with blood.

The pia mater is a much softer and thinner membrane than the former ; it is connected to the dura mater only by the veins which open into the sinuses. The pia mater consists of two laminae ; the external of these, from its extreme thinness, has been compared to the spider's web, and is named tunica arachnoidea ; at the upper part of the brain it is connected both to the dura mater and the internal lamina of the pia mater, by means of blood-vessels, but in other parts it is quite separate from both. It is spread uniformly over the surface of the brain, inclosing all the convolutions, but not entering between any of them.

On the contrary, the internal and most considerable lamina of the pia mater is not only insinuated into the numerous folds and circumvolutions of the brain, but is continued into its cavities, performing the important office of conveying the blood-vessels to that delicate organ in such a minute state of division, that their pulsation cannot be prejudicial to its functions.

The brain completely fills the cavity of the cranium, and its form therefore corresponds with it ; it is convex above, irregular below, and flat at the sides. Under the general name of brain, or encephalon, are included the cerebrum, which occupies the upper and largest portion of the cranium, and the cerebellum, which is seated in its lower and posterior part, under the transverse septum. The cerebrum

brum is divided longitudinally at its upper part, by the falx, into its two hemispheres. The irregular surface of the cranium below divides each hemisphere into three lobes. The anterior lobe is lodged on the orbital processes of the os frontis; the middle lobe lies in the middle fossæ of the basis of the cranium; the posterior rests on the transverse septum over the cerebellum. The cerebellum is itself divided into two hemispheres by the small falx.

The component matter of the brain is of two kinds; a greyish matter, which is for the most part placed without, and is therefore called the cortical, and a white matter called the medullary, which is generally situated within. The cortical part chiefly accompanies the convolutions of the brain; the medullary is entire, and seems to be composed of numerous white, minute, parallel, and very tender fibres.

Having removed the falx from between the hemispheres of the brain, and drawn them gently from each other, we observe below a white convex surface, which is part of what is called the corpus callosum. It is a middle portion of the medullary substance, which, under the inferior edge of the falx, and for some distance on each side, is parted from the mass of the cerebrum by a fold of the pia mater. Along the middle of the surface of the corpus callosum, a kind of raphe or suture is formed by a particular intertexture of fibres crossing each other. Immediately under these is placed the septum lucidum, which is connected below to the fornix, and divides

divides the anterior ventricles of the brain from each other. These ventricles are discovered by making an horizontal incision in the brain, on a level with the corpus callosum. When we have cut into them, we find that they are narrow canals, which take a very winding course through the substance of the brain. They are lined with the pia mater, and contain a curious collection of minute blood-vessels twisted about each other, and called *plexus choroides*. One of the anterior ventricles is situated in each hemisphere of the brain, and they are divided from each other by the *septum lucidum*.

The *septum lucidum* is united by its lower part to the anterior portion of that medullary body called the fornix, which forms a kind of arch, situated under the corpus callosum, and is nearly of a triangular shape. At the anterior part the fornix sends off a double medullary cord, called its anterior crura; immediately below which we observe a large white medullary rope stretched transversely between the two hemispheres, and commonly called the anterior commissure of the cerebrum. To this substance the *septum lucidum* is connected. At the posterior part of the fornix are two other crura, which unite with two medullary protuberances called *pedes hippocampi*. Under the fornix, and immediately behind its anterior crura, there is a hole by which the two anterior ventricles communicate. In examining the substance of the cerebrum, the deeper we go towards the basis of the cranium, we find that the medullary part becomes the broader.

The *plexus-choroides* is a very fine vascular texture, consisting of a great number of arterial and venal

venal ramifications, spread over the lateral or anterior ventricles. When we have removed this plexus, we discover several protuberances included in these cavities. These are the corpora striata, the thalami nervorum opticorum, and the nates and testes.

The corpora striata are two curved oblong eminences, which extend along the anterior part of the lateral ventricles. They are called striata or striped, because in cutting them we meet with a number of white and ash coloured lines alternately disposed. These two eminences are of a greyish colour on the surface, and larger before than behind, where they are narrow and bent. They may be considered as forming the convex bases of the ventricles.

The thalami nervorum opticorum are externally white, but also contain both cortical and medullary substance, and derive their name from being the chief source of the optic nerves. They are two eminences placed near each other, between the posterior portions or extremities of the corpora striata. They are closely united, and at their convex part form one body. Immediately under the union of the thalami nervorum opticorum lies a cavity called the third ventricle of the cerebrum. This cavity communicates at its upper and fore part with the passage between the two lateral ventricles, and sends down from its under and fore part a passage through the infundibulum; it has a communication backwards with the fourth ventricle.

The infundibulum is a small medullary canal, situated between the basis of the anterior pillar of the

the fornix, and the anterior part of the union of the thalami nervorum opticom. It runs downwards, and terminates by a small membranous canal in a softish body, situated in the sella turcica of the sphenoidal bone, and called glandula pituitaria. This substance was so named by the ancients, from its supposed office of cleansing the brain from ferous fluids. Its real use is wholly unknown. In ruminant animals it is much larger than in man.

The nates and testes, or as they are otherwise denominated, tubercula quadrigemina, are four tubercles, situated behind the union of the thalami nervorum opticom, adhering to each other. They are externally white, and their internal substance is greyish. Between the two anterior tubercles and the convex part of the thalami nervorum opticom is an interstice called foramen commune posterius. This, however, is closed by the pia mater, and does not open into any cavity.

Above the tubercula quadrigemina, and behind the thalami nervorum opticom, is fixed the pineal gland. This body is of an oval form, about the size of a pea, and is connected to the lower part of the thalami by two very white medullary pedunculi. It seems to be mostly formed of cortical substance, particularly at its upper part, and adheres closely to the plexus choroides, with which it is covered. This small body has been rendered famous by Descartes, who supposed it to be the seat of the soul. It is often found, on being cut into, to contain a gravelly substance, which resists the knife. Below the pineal gland there is a transverse medullary cord, called the posterior commissure of the hemispheres of the cranium.

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The cerebellum is situated under the transverse septum, in the posterior and lower part of the cranium. Like the cerebrum it is composed of cineritious and medullary matter. It differs from the cerebrum, however, in having no circumvolutions on its surface ; instead of these, we here observe numerous furrows running parallel to each other, and nearly in a transverse direction, into which enter folds of the pia mater. Under the transverse septum it is covered by a vascular texture which communicates with the plexus choroides. It has four eminences which are turned in different directions, and which from some resemblance to the rings of an earth-worm are named appendices vermiformes. The cerebellum is divided into two lateral parts by the small falx ; on the back part it is divided into two lobes separated by the occipital septum of the dura mater.

By cutting deeply into the substance of the cerebellum in the direction of its falx, we observe an oblong cavity which is called the fourth ventricle ; this terminates backwards like the point of a writing-pen, and this end of it has therefore been called calamus scriptorius. At the beginning of this cavity we meet with a thin medullary lamina which has been considered as a valve. This ventricle is lined like the others with the pia mater, which is continued through all these cavities.

The substance of the cerebellum appears very different, according to the direction in which it is cut. By dividing it vertically we find the medullary part disposed so as to exhibit the appearance of a tree. These ramifications unite to form a me-

dullary trunk ; the middle, anterior, and most considerable part of which forms two processes, the crura cerebelli, which uniting with the crura cerebri constitute the medulla oblongata, which will be next described; when the cerebellum is cut horizontally this appearance is entirely lost.

The medulla oblongata is situated in the lower and posterior part of the cranium, and is formed of two considerable medullary processes of the cerebellum, and of the two larger processes of the cerebrum called their crura. It may therefore be considered as a medullary mass common to both cerebrum and cerebellum, by the reciprocal continuity of their substances through the great notch in the transverse septum. The medulla oblongata can only be seen when removed from the cranium, and the description can only apply to the parts when viewed in their inverted situation.

The crura cerebri arise from the middle and lower part of each hemisphere. Where they arise from the cerebrum they are separate, but converge as they run backwards so as to resemble the letter V. Where they unite they form a middle transverse protuberance called the pons Varolii, because that anatomist compared it to a bridge, and the two crura cerebri to two rivers. This comparison, however, conveys no idea of the real appearance of the parts, and the pons Varolii is to be considered merely as an eminence formed by the union of the crura of the cerebrum and cerebellum.

Between the crura cerebri and near the anterior edge of the pons Varolii are two white eminences, named eminentiæ mamillares. From the posterior

part of the pons Varolii the medulla oblongata is contracted, and descends obliquely backwards to the foramen magnum of the os occipitis, where it terminates in the medulla spinalis. In this part of it several appearances are to be noticed. We observe four eminences, two named the corpora olivaria, and the other two the corpora pyramidalia. Immediately behind these we discover the beginning of two grooves, one above and one below. These becoming deeper divide the medulla oblongata into two cylinders. When we separate these with the fingers we observe several medullary cords which cross each other in passing from one lateral portion to the other.

The corpora olivaria and pyramidalia are whitish eminences situated longitudinally near each other immediately behind the pons Varolii. The corpora olivaria are outermost and are nearly of an oval shape. Between them are the corpora pyramidalia, each of which terminates in a point.

It is observable, in general, with respect to the eminences of the medulla oblongata, that those which are medullary without are chiefly cortical within. What are the distinct functions of these substances which appear so different to the eye, and what purposes are answered by their intermixture, are points which must remain undetermined till we can discover the connection between the mind and the body, and enter into the secret mechanism of this wonderful engine of sensation and intellect.

The brain of birds is covered with the common membranes, but its external surface is not formed into so many gyræ or convolutions as ours. Its

anterior part is quite solid, of a cineritious colour, and so far has a resemblance of the corpora striata as to give rise to the olfactory nerves. The whole of it appears to us imperfect, and we can scarcely distinguish whether there is any thing analogous to a third or fourth ventricle : neither the *corpus callosum*, *forix*, *nates* or *testes* can be observed here : which parts therefore cannot be considered as necessary to the functions of life ; we might however be led to imagine, that they are subservient to the superior intellectual powers of the human mind, did we not find that quadrupeds have these parts as well as men. These appearances seem rather to depend on the various disposition and direction of the fibres which compose the brain, and the particular uses which have been assigned to the different parts of the brain seem to have no other foundation than the fancy of authors, who have indulged themselves in fruitless speculations. Those birds which seek their food below the surface of water, mud, &c. have large nerves which run quite to the extremity of the bill, by which the sensation of that part is rendered more acute.

From the medulla oblongata, which is formed by the union of the cerebrum and cerebellum, arise not only the spinal marrow, but almost all the other nerves which perforate the basis of the cranium.

The medulla spinalis, or spinal marrow, is a continuation of the medulla oblongata, which passes through the great foramen of the cranium, and is continued down the bony canal formed by the vertebræ. The figure of the spinal marrow is compressed, being flatter behind than before, where we
2 observe

observe a continuation of those grooves which divide the medulla oblongata into its lateral portions. In the medulla spinalis these appear like two cords closely applied to each other, but which may be easily separated both before and behind till we come to their middle, where they are joined together by a thin layer of cineritious substance passing from one cord into the other. The spinal marrow, like the parts of which it is a continuation, consists of medullary and cineritious substance; the former, however, is here placed without; the cineritious is placed within, and by a transverse section of the medulla spinalis it appears to be in the form of a horse-shoe, the convex side of which is turned forwards and its extremities backward.

The spinal marrow is invested both with the dura and pia mater. The former of these in passing out of the foramen of the os occipitis, forms a kind of funnel, adhering at its upper part to the ligamentary substance which lines the bony canal of the vertebræ. Lower down there is no adhesion, except where the nerves pass through the notches of the spine, where the dura mater, which invests the medulla spinalis, sends out on each side the same number of sheaths as there are ganglions and nervous trunks.

The pia mater is connected with the dura mater by means of a thin transparent substance, which from its indentations between the spinal nerves has been named the ligamentum denticulatum. Its use is to support the medulla spinalis, that it may not affect the medulla oblongata, or spinal nerves by its weight. The lower end of the ligamentum denticulatum

runs to the os coccygis far below the termination of the spinal marrow.

Each lateral portion of the medulla spinalis sends off, both from the fore and back parts, flat fasciculi of nervous fibres. The anterior and posterior fasciculi are separated from each other by the ligamentum denticulatum; then passing outwards they proceed through the dura mater by two distinct openings very near each other. Having penetrated the dura mater, the posterior bundle forms a ganglion, from the opposite end of which the trunk comes out again, and is there joined by the anterior bundle.

The membrana arachnoides is here very distinct from the internal lamina of the pia mater; so that by blowing through a hole made in the arachnoides, it will swell from one end to the other like a transparent intestine.

The spinal marrow gives rise to about thirty pair of nerves. Those which come out between the vertebræ of the neck are thinner than the rest, and are placed almost transversely; as we descend, we find them running more and more obliquely downwards, and when we arrive at the second vertebra of the loins, the spinal marrow is split into numerous thread-like fibres, and from its appearance is called *cauda equina*, or the horse's tail. The nerves which arise from the different parts of the brain and spinal marrow will be treated of in a separate chapter.

C H A P. XXVIII.

STRUCTURE AND GENERAL DISTRIBUTION OF
THE NERVES.

Origin of the Nerves.—Extreme subtilty of the Nervous Fibres.—Ganglions.—Plexus.—Fontana's Microscopical Observations on Nerves.—Nerves from the Brain.—Olfactory and Optic Nerves, &c.—Auditory Nerves, &c.—Lingual Nerves, &c.—Sympathetic Nerve.—Nerves from the Spinal Marrow.—Phrenic Nerve.—Dorsal and Brachial Nerves, &c.—Lumbar and Crural Nerves, &c.—Sciatic Nerve.

NERVES are white cords distributed from the brain over the whole body; they rise, as was intimated in the preceeding chapter, either immediately from the brain or mediately from it by means of the spinal marrow, which is itself a continuation of the fibres of the brain, and might without impropriety be considered as the largest nerve in the body. The nerves, as they pass off from the brain and spinal marrow are invested, and collected into firm cords, by the dura and pia mater. The former, however, is soon reflected back, but the latter accompanies them through all their ramifications, and is supposed to be only thrown aside where they terminate in their sentient extremities.

As the medullary fibres are observed to decussate each other in different parts of the brain, and as injuries of one side of the head have often been observed to produce a palsy of the opposite side of the body, it has been supposed that all the nerves

originate from the side of the brain opposite to that at which they come out. This opinion, however, is far from being established, because a decussation in some parts is by no means a proof that it obtains universally; and though there are instances of injuries of the head, which have produced a palsy of the opposite side, there are others in which the injury and palsy were both on the same side.

Nerves are composed of threads of the smallness of which we have probably no adequate idea. To assist us in forming one, we must consider how uniformly nerves are distributed to even the most minute fibre of the body, and yet were they all conjoined, they would not make a cord of an inch diameter. It is deduced from actual observation, that each fibre in the retina of the eye, or expanded optic nerve, cannot exceed in diameter the thirty-two thousand four hundredth part of a hair.

Different nerves in their course often meet together, and form oblong reddish masses, called ganglions, larger than the nerves which form them, and also of a firmer consistence. Within the ganglions the fibres of the nerves seem to be thoroughly mixed, and to approach more nearly to the nature of medullary matter. By some physiologists ganglions are supposed to be small brains, whence the nerves acquire new power and energy. Others, observing that the nerves which supply the muscles of involuntary motion, as those of the heart and intestines, are particularly supplied with ganglions, have considered them as designed to intercept the operation of the will. Their real use is unknown to us, but from whatever cause it may happen, the
nerves

nerves which proceed from a ganglion are rather larger than the sum of those which form it.

Several nerves frequently meet together, and by numerous junctions produce an appearance similar to that of net work, and this is called a plexus.

Nervous cords have very little elasticity compared with some other parts of the body.

The Abbè Fontana has taken great pains to ascertain the primitive structure of nerves. On examining a number of nerves with microscopes of low powers, so as not to magnify more than four or five diameters, they always appeared to be surrounded with white spiral bands not unlike the effect which would be produced by a ribbon twisted round a cylinder. The spiral bands were sometimes perfectly regular, so as to be of equal width along the whole length of the nerve examined, and to leave a space of a less bright colour of the same width between them; at other times they were irregular and crossed each other at uncertain distances; this latter appearance, however, was found on further examination to proceed from the nerve submitted to examination being composed of many others: for where he carefully separated a nerve from those which adhered to it, and examined it by itself, he always found the spiral bands regular. He saw these appearances very plainly in nerves not larger than a hair, with lenses of very small power, and was therefore persuaded that this appearance of bands was not an optical illusion.

The same nerve, however, which to the naked eye, and by a lens of small power exhibited this appearance,

appearance, when examined by a microscope of high powers, appeared to consist merely of parallel but twisting fibres.

He next removed the cellular tissue or sheath of a nerve, without injuring its texture; but still with a microscope of high powers he could perceive nothing but waving and twisting fibres, and nothing but spiral bands with the naked eye. After applying, however, to these observations for two or three days, he found, that by merely moving the reflecting mirror, he sometimes saw twisting fibres and sometimes spiral bands with the same lens. He is therefore under a necessity of giving up his supposed discovery, and of allowing that the spiral bands were merely an optical deception.

From his observations he can deduce no more than that nerves are formed of a great number of transparent, homogeneous, uniform, and very simple cylinders. That these cylinders are formed by an extremely thin tunic, uniformly filled by a gelatinous transparent humour, which is insoluble in water; each of these cylinders is covered by an external sheath which is composed of a great number of twisting threads. Many transparent cylinders constitute a nerve which is scarcely visible to the naked eye, and many of these form the nervous cords which are seen in animals.

The Abbè Fontana also submitted to the microscope the medullary and cortical parts of the brains of several animals. In these, however, the appearances were pretty similar, and the substance of both appeared to be organic, vascular, transparent, and twisting, like intestines.

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The nerves proceed from the encephalon and spinal marrow. Ten pair are usually enumerated as arising from the former, and thirty from the latter. I shall first describe the origin and course of those of the encephalon. Anatomists mention these in the order in which they present themselves when the brain is lifted from the cranium; those which come from the anterior part of the cerebrum are therefore placed before those which arise lower down from the cerebellum and medulla oblongata.

The first pair of nerves is the olfactory, which proceed from the corpora striata; they approach the cribriform plate of the os ethmoides, where they split into a great number of filaments, which pass through the perforations of that bone. Afterwards being joined by a branch from the fifth pair, they are spread on the internal membrane of the nose, and constitute the organ of smelling.

The second pair of nerves is the optic, which are continued from the thalami nervorum optictorum, and are of a large size; they first make a large curve outwards, and then run obliquely inwards and forwards, till they unite at the fore part of the sella turcica; they then divide, and each runs to its proper foramen in the sphenoid bone. They are accompanied to the eye by the ocular artery, and are at length expanded into the tender and pulpy substance of the retina, which receives the impressions of light. The union of the optic nerves has been thought to explain some phenomena of vision, as our seeing objects single with two eyes, and their uniform motion. The union of the optic
nerves

nerves generally appears so [considerable, that some anatomists have thought that they decussated each other, and went to the eye on the opposite side of the head from that whence they arose. In many fishes the optic nerves evidently cross each other, but this does not seem to be the case in man. They are inserted into the eyes, not directly at their posterior part, but rather towards that side which is placed next the nose. We are unable to see with that part of the retina where the optic nerve enters.

The third pair called *motores oculi* arises from the *crura cerebri*, near the *pons Varolii*; they run along the side of the *fella turcica*, and pass out at the *foramina lacera*, after which each of them divides into branches; one of these, after forming a ganglion, is distributed to the globe of the eye; the others are sent to the *musculus rectus* of the *palpebra*, and to the *attollens*, *adductor*, *deprimens*, and *obliquus minor* muscles of the eye ball.

The fourth pair of nerves called *pathetici*, are the smallest of all; they arise from near the *tubercula quadrigemina*; they pass out at the *foramina lacera*, and are entirely spent on the *musculi trochleares* or superior oblique muscles of the eye balls.

The fifth pair is the largest of those which proceed from the head; they rise from the *crura cerebelli*, where they join with those of the *cerebrum*, to form the transverse protuberance or *pons Varolii*. In their progress they appear thicker at the sides of the *fella turcica*, where each forms a distinct

distinct ganglion, from which proceed three branches, which pass out of the cranium.

The first branch of the fifth pair is the ophthalmic; it passes out of the foramen lacerum, and is in its passage connected with the sixth pair; it afterwards communicates with the first and third pairs, and is chiefly spent on the orbit and the appendages of the eye. One branch passes through the foramen superciliare of the os frontis, to be distributed on the forehead.

The second branch of the fifth pair is chiefly spent on the parts of the upper jaw, and is therefore called maxillaris superior; it is distributed on the upper jaw bone and its teeth, on the fore part of the palate, the cheeks, upper lips, and nostrils. This branch communicates with the sixth pair of nerves, and with the portio dura of the seventh pair.

The third and most considerable branch of the fifth pair is the maxillaris inferior; part of this is lost in the tongue; another part goes to the teeth of the lower jaw, to each of which it sends a separate twig; it is partly also distributed on the muscles of the lower jaw.

The sixth pair of nerves is small, and is chiefly distributed on the abductor muscle of the eye; it arises from the forepart of the corpora pyramidalia, and in its progress towards the foramen lacerum passes through the receptacula at the sides of the fella turcia, where it is immersed in blood, but for what purpose is unknown. In the passage of this nerve below the dura mater, it lies very contiguous to the carotid artery, and at this part a twig from it descends

descends with the artery to form the beginning of the intercostal nerve.

The seventh pair comes out from the lateral part of the transverse protuberance, and appears to be double, each being accompanied with a larger artery than most other nerves; it then enters the internal meatus auditorius, where it separates into two distinct portions; one of these goes to the internal parts of the ear, and is there expended in producing a pulpy membrane resembling the retina; this division of the nerve is called the *portio mollis*; the other, the *portio dura*, communicates with the fifth pair, and piercing through the parotid gland is divided into numerous ramifications which are spent on the upper part of the neck and side of the head.

The eighth pair of nerves, which from the length of its course and the variety of parts to which it is distributed is called *par vagum*, arises from the lateral bases of the corpora olivaria in separate fibres. The eighth pair is soon joined by the *nervus accessorius* which is derived from the tenth pair of nerves, and from several of those of the neck; thus united, they pass out of the cranium through the same opening with the internal jugular vein; when they get out of the cranium the *nervus accessorius* leaves the eighth pair, and passing through the *sterno mastoideus* muscle, is distributed on that and the *trapezius*. The eighth pair now disperses various branches to the tongue, larynx, and pharynx, which are united with branches of the fifth pair, with the *portio dura* of the seventh pair, with the recurrent nerve, with the great intercostal, and with the ninth pair and all the cervical nerves. Being
separated

separated from these nerves it runs down on the external side of the carotid artery, and as it is about to enter the thorax a considerable nerve called the recurrent is sent off on each side. The right recurrent nerve takes a turn round the right subclavian artery, and the left round the aorta; and both of them running up again at the side of the œsophagus to which they give branches, are spent on the parts of the larynx. We find from many instances that nerves court the neighbourhood of arteries, but what are the purposes of such a distribution it is not easy to determine.

At the part from which the recurrent nerves arise, are also sent off twigs which join with the branches of the intercostal, and which are distributed on the heart, where they form a plexus on the pericardium. The two trunks of the eighth pair now descend by the œsophagus to the stomach, where plexuses are produced, whence the stomach is plentifully supplied with nerves, and some are sent to the diaphragm, the liver, and the pancreas. From these are sent branches, which contribute to form plexuses on the spleen and kidneys. Near the cæliac artery the eighth pair also unites with the great semi-lunar ganglion, formed by the two intercostal nerves. I have been the more particular with regard to the eighth pair of nerves, merely to give the reader an idea of the very complex manner in which the nerves are united to each other, and to evince the careful provision which is made to supply the most important viscera from a variety of sources.

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The ninth pair or lingual, rises from the inferior part of the corpora pyramidalia and passes out through the occipital bone. After they have arrived on the outside of the cranium they adhere firmly for some way to the eighth and the intercostal; then after sending a branch to communicate with the cervical nerves they enter the tongue and are lost in its substance.

The tenth pair of the head is by some anatomists considered as the first of the vertebral. It rises by separate threads from the side of the spinal marrow, passes out between the os occipitis and first vertebra of the neck, and after having given branches to the great ganglion of the intercostal, and some of the cervical nerves, is lost in the adjoining muscles.

It has been already mentioned that a branch of the sixth pair of nerves, joined by a twig from the fifth, accompany the internal carotid artery through its bony channel, and passing out of the cranium, constitute the beginning of the great intercostal or sympathetic nerve. As soon as the nerve has got without the cranium it is connected a little way with the eighth and ninth pairs; separating from these it forms a large ganglion, into which enter branches from the tenth of the head and from the first and second pairs of the cervical nerves. Thence running down the neck with the carotid artery, and distributing nerves to the adjoining muscles, it forms another ganglion as it is about to enter the thorax, whence nerves are sent to the trachea and heart; those which go to the heart being united with nerves from the eighth pair. Below the subclavian artery the fibres of the intercostal unite to form a third ganglion,

ganglion. After this the trunk of the intercostal passes down by the spine, close to the transverse processes, through the cavity of the thorax. In this course all the dorsal nerves as they come from the spine contribute to its increase by the addition of twigs on each side. Descending still lower it receives similar accessions from the nerves which come out between the lumbar vertebræ and os sacrum. At the extremity of the os coccygis the intercostals of the opposite sides are turned inwards and unite with each other. The intercostal is larger in the thorax than it is either above or below.

From the part whence the fifth, sixth, seventh, eighth and ninth dorsal nerves are sent to the intercostal, come out as many branches, which form an anterior trunk called the small intercostal nerve. This passes through the posterior part of the diaphragm to form with the great intercostal of the opposite side, and with the eighth pair, a large semi-lunar ganglion, situated between the cæliac and superior mesenteric arteries. From this ganglion, as from a centre, nerves are sent to the liver, pancreas, spleen, duodenum, jejunum, ileum, and a large part of the colon.

Several fibres also passing downwards on the aorta are joined by other nerves from the posterior trunk of the intercostal, and form plexuses which supply the kidneys, glandulæ, suprarenales, &c. They also form a plexus about the inferior mesenteric artery, which accompanies its branches to that part of the colon which lies at the left side of the abdomen, and to the rectum.

The first cervical pair of nerves comes out between the first and second cervical vertebræ; the second cervical pair between the second and third. These nerves communicate with each other and with those nerves of the head which pass down to the neck. They are afterwards chiefly spent on the extensors of the head, the levators of the scapulæ, and the neighbouring integuments.

The third cervical nerve passes from the spinal marrow, between the third and fourth vertebræ, and joining with the fourth cervical, forms the phrenic nerve, which passes down by the subclavian vessels in its way to the diaphragm, on which it is expended. The other branches of the third pair are distributed to the muscles of the neck and top of the shoulder. Hence it has been attempted to account for the pain at the top of the right shoulder in inflammations of the liver. The diaphragm is supposed to be affected either by its contact with the liver, or by the increased weight of that viscus pulling it downwards; and the shoulder is thought to sympathize with the diaphragm, because it receives nerves from the same source. This explanation, however, is very unsatisfactory, since nothing is more common than for parts to be supplied by the same nerves without having any such sympathy.

The fourth cervical nerve, after having given off that branch which joins with the third to form the phrenic, passes to the axilla, where it forms a plexus with the fifth, sixth, and seventh cervical nerves, and with the first of the dorsal. After giving several considerable nerves which are distributed on the muscles of the thorax, they form several branches which

which pass down on the arm, and supply the whole superior extremity.

The dorsal nerves are twelve in number, and all contribute to the formation of the great intercostal. The first of the dorsal nerves differs from the rest in contributing to the formation of the brachial nerves, and in forming a large ganglion with the intercostal nerve.

The dorsal nerves also give branches backwards to the strong muscles situated on the spine, and which serve to erect the body. Their principal trunks accompany the intercostal arteries in the groove at the bottom of each rib, and are distributed with them to the sides and anterior parts of the thorax. The six lower dorsal nerves also give branches to the diaphragm and abdomen. The twelfth joins the first and second of the lumbar, and bestows nerves on the quadratus lumborum, psoas, and iliacus internus.

The first and second of the lumbar nerves send branches, which join with others from the third and fourth, and form a large nerve which passes through the foramen thyroideum, and is spent on the muscles and integuments at the inside of the thigh; it is called the obturator or posterior crural nerve. By branches from the four upper lumbar nerves is also formed the anterior crural nerve, which passes out of the abdomen under the ligament of Fallopius, and is distributed on the integuments and muscles at the fore part of the thigh. A branch of this nerve also attends the vena saphena to the foot.

The fourth and fifth lumbar nerves contribute with the three superior sacral nerves to form the

largest nerve of the body, the sciatic. This nerve, after giving nerves to the muscles about the hips, passes behind the tuberosity of the ischium, and then downwards, close to the posterior part of the os femoris. Distributing nerves through its whole progress it runs down the back part of the leg, and terminates in the sole of the foot. The fourth, fifth, and sixth anterior sacral nerves are much smaller than the superior, and are chiefly distributed on the bladder, rectum, and anus. Small nerves pass through the posterior openings of the os sacrum, which are distributed on the hips and neighbouring muscles.

Nerves may more properly be said to be connected with the brain than to be produced from it, since foetuses have been born with a brain not larger than a hazel nut, and yet with nerves of the usual size.

The uses of the nerves are very important, but are best discovered from observing the effect of their absence. When a nerve is cut or tied, the part to which it belonged is instantly deprived of sensation, and the will has no longer any command over it. The nerves are therefore the instruments of sensation, and the organs by means of which the brain maintains a communication with the most distant parts of the body.

After having considered the structure of the different parts of the human body, can we refrain from pausing a few moments to contemplate so wonderful a fabric? But man is only a single instance of the wisdom of Providence; every part of the world contains animals, the structure of which is not less

complex than our own, and the constitutions of which are suited to the climates they inhabit. All of them are furnished with organs for their subsistence, their defence, and their enjoyment, and these organs are adapted to their several necessities, and have corresponding relations in the objects, as well animate as inanimate, which surround them. Not only the surface of the earth, however, but the atmosphere, the ocean, the herbage, the soil; teem with the animal creation. How far this system may extend we know not; but observation has hitherto continually enlarged our prospects, without marking a single limit; and it is not improbable, that the animal which dwells on the body of another, may itself be a theatre of life, on which still more minute animals take their sport and pastime.

From these views shall we turn to the heavenly bodies, and suppose that such vast masses of matter are destitute of inhabitants? The planets as well as the earth receive the rays of the sun, and some of them which are far removed from his light, are furnished with moons. Were these moons, which are only visible by the telescope, designed for our amusement, or for the use of beings placed sufficiently near to profit by their influence? What shall we think of those still larger bodies, the stars, which multiply upon us without end, in proportion as we are furnished with more extensive means of observing them. But the Deity has placed no bounds to our admiration; for he has made space appear to the human mind necessarily infinite, and time, everlasting.

The figure in the annexed plate (XIV.) represents the distribution of the nerves.

a, A part of the first branch of the fifth pair of nerves, called the ophthalmic branch, going out of the orbit, and winding upon the forehead.

b, The orbital branch of the second branch of the fifth pair, going out at the foramen below the orbit, and distributing its branches on the lower part of the face below the eye.

c, A part of the maxillary branch of the third branch of the fifth pair of nerves, going out by a canal in the lower jaw-bone by the side of the chin and lower lip.

d, The trunk of the eighth pair of nerves, joined with the recurrent nerve.

e, The trunk of the eighth pair of nerves cut off.

f, The spinal recurrent nerve. *g*, A branch of it belonging to the cleidomastoideus and sternomastoideus muscle.

h, The conjunction of the recurrent nerve with the third of the cervical nerves. Afterwards the recurrent winds backwards.

i. i. i., The left intercostal nerve.

k, The upper cervical ganglion of the intercostal nerve.

l, A branch of the second cervical nerve, going to join the ganglion *k*.

m, A branch of the first cervical nerve, going to the same ganglion *k*.

n, o, Branches from the cervical nerves, going to the intercostal nerve.

- p*, The ganglion of the intercostal nerve in the upper part of the thorax.
- q, q*, &c. Branches, by which the intercostal nerve is conjoined with the spinal nerves; viz. by the seventh and eighth of the cervical, and all the dorsal and lumbar.
- r, s*, The extremity of the intercostal nerve, belonging to the first nerve *r*; and the second *s* of the os sacrum.
- t*, A considerable nerve, arising from the intercostal near the vertebræ of the back; here indeed it has six beginnings, according to those branches by which the intercostal is joined with the fourth, fifth, sixth, seventh, eighth, and ninth dorsal. Which nerve, here cut off, passes through the diaphragm into the abdomen, where it joins itself with the eighth pair of nerves of the brain, and with other branches of the intercostal nerve, &c.
- u*, A branch of the intercostal nerve.
- w, w*, &c. Branches by which the right intercostal nerve is joined with the spinal nerves.
- x, y*, Those branches of the right intercostal, which *r, s*, represent of the left.
- z, z*, Branches.
- A, A*, Branches.
- B, B*, The first pair of cervical nerves.
- C, C*, Branches, by which the second pair of cervical nerves is joined with the third.
- D, D*, The second pair of cervical nerves.
- E, E*, Branches, by which the third pair of cervical nerves is joined with the fourth.
- F, F*, The third pair of cervical nerves.

G, G, The fourth pair of cervical nerves.

H I K, H I K L, The phrenic nerves, arising by two origins, the one H from the fourth cervical pair, and the other I from the fifth. K, K, Their trunks, the left of which, upon account of the point of the heart's being turned to the left side, is bended towards the left. L, The extremity of the right, branched out upon the diaphragm.

M, M, The fifth pair of cervical nerves.

N, N, The sixth pair of cervical nerves.

O, O, The seventh pair of cervical nerves.

P, P, Branches of the first pair of dorsal nerves, going to join the eighth pair of cervicals.

Q, R, &c. The costal branches of the dorsal nerves, which run according to the length of the ribs.

Q, Q, The first, R, R, the second, S, S, the third, T, T, the fourth, U, U, the fifth, V, V, the sixth, W, W, the seventh, X, X, the eighth, Y, Y, the ninth, Z, Z, the tenth, α , α , the eleventh, β , β , the twelfth.

d, A branch of the second costal nerve, which passes through the external intercostal muscle, immediately under the origin of the serratus magnus, which proceeds from the second rib; afterwards it bends itself backwards according to the direction of the origin of the serratus magnus, and then distributes itself upon the outside of the latissimus dorsi under the skin.

e, A similar branch of the third costal nerve, passing through in the same manner, and distributed as the former.

z, A similar

- ζ, A similar branch of the fourth costal nerve, which, when it has got under the skin, winds partly backwards, and partly forwards and downwards.
- η, A similar branch of the fifth costal nerve, which passes first through the external intercostal muscle, then through the head of the external oblique, that part of it which rises from the fifth rib, and afterwards runs along under the skin.
- θ, ι, κ, Branches of the seventh θ, the eighth ι, and the ninth costal nerve κ, distributed to the internal part of the external oblique muscle of the abdomen.
- λ, A branch of the tenth costal nerve, which, after having passed through the external intercostal muscle and the transverse, runs forwards between the transverse and internal oblique muscles towards the rectus muscle, and passes through it likewise by the aponeuroses of the oblique muscles to the parts below the skin.
- μ, A branch of the eleventh costal nerve, which follows the same course with that of the tenth, λ.
- ν, A branch of the tenth costal nerve, bestowed upon the inside of the internal oblique muscle.
- ξ, A branch of the eleventh costal nerve, bestowed the same way as the last, ν.
- , π, These appear to be branches of the twelfth costal nerve, running between the transverse and internal oblique muscles.

ρ, This

- ς, This is a branch of the first pair of lumbar nerves, running likewise between the transverse and internal oblique muscles.
 ς, ς, Branches of the twelfth pair of costal nerves.
 τ, τ, The first pair of lumbar nerves.
 υ, A branch of the first pair of lumbar nerves.
 φ, The second pair of lumbar nerves.
 χ, The second of the lumbar nerves, joins with the third, and with the upper root of the nerve 1.
 ψ, A nerve, marked Φ, on the left side, arising here by a double origin, one from the first pair of lumbar nerves, and the other from the second.
 ω, The third of the lumbar nerves.
 Γ, The fourth of the lumbar nerves.
 Δ, A branch, which is sent from the fourth pair of lumbar nerves to join the sciatic.
 Θ, Θ, The fifth pair of lumbar nerves.
 Λ, Λ, The first pair of nerves of the os sacrum.
 Ξ, Ξ, The second pair of nerves of the os sacrum.
 That on the right side is joined by an intermediate branch with the third.
 Π, Π, The third pair of nerves of the os sacrum.
 Σ, Σ, The fourth pair of nerves of the os sacrum.
 Φ, A nerve, whose origin is marked Ψ on the left side, emerging from the great psoas muscle, and going down along with it into the groin.
 Ψ, A nerve, which arises by a double origin from the second lumbar nerve φ, where its roots are cut through.
 Ω, A branch of the crural nerve, which is conjoined into one with the nerve, ψ.
 Ι, Ι, A considerable nerve on each side, which arising by two roots, the one from the second and

- and third, and the other from the fourth of the lumbar nerves, runs down first under the great psoas muscle, then by the side of the pelvis to the upper part of the foramen thyroideum, where it divides into two branches, the anterior, 2, and the posterior, 3.
- 2, The anterior, goes out immediately above the obturator muscle by a sinus, in the upper part of the foramen thyroideum.
- 3, 3, 4, The posterior, passes through the same sinus, and, running immediately down between the two obturators, gives a branch to the external; it goes out then by that external branch, 4.
- 5, The sciatic nerve.
- 6, 6, The crural nerves.
- 7, 7, Branches of the crural nerves, going to the internal iliacs.
- 8, 8, The external branches of the crural nerves, which, running down the thighs, give branches to the internal iliac muscles, the musculi recti of the leg, the vasti interni, the crurei, and the vasti externi.
- 9, 9, The internal branches of the crural nerves, which run down the thigh, and in their course give off branches to the vasti interni
- 10, 10, The roots of the nerves.
- 11, 11, The roots of the nerves.
- 12, Here the internal branch of the right crural nerve, emerging between the muscles gracilis and sartorius, is cut off.
- 13, The root of that branch.

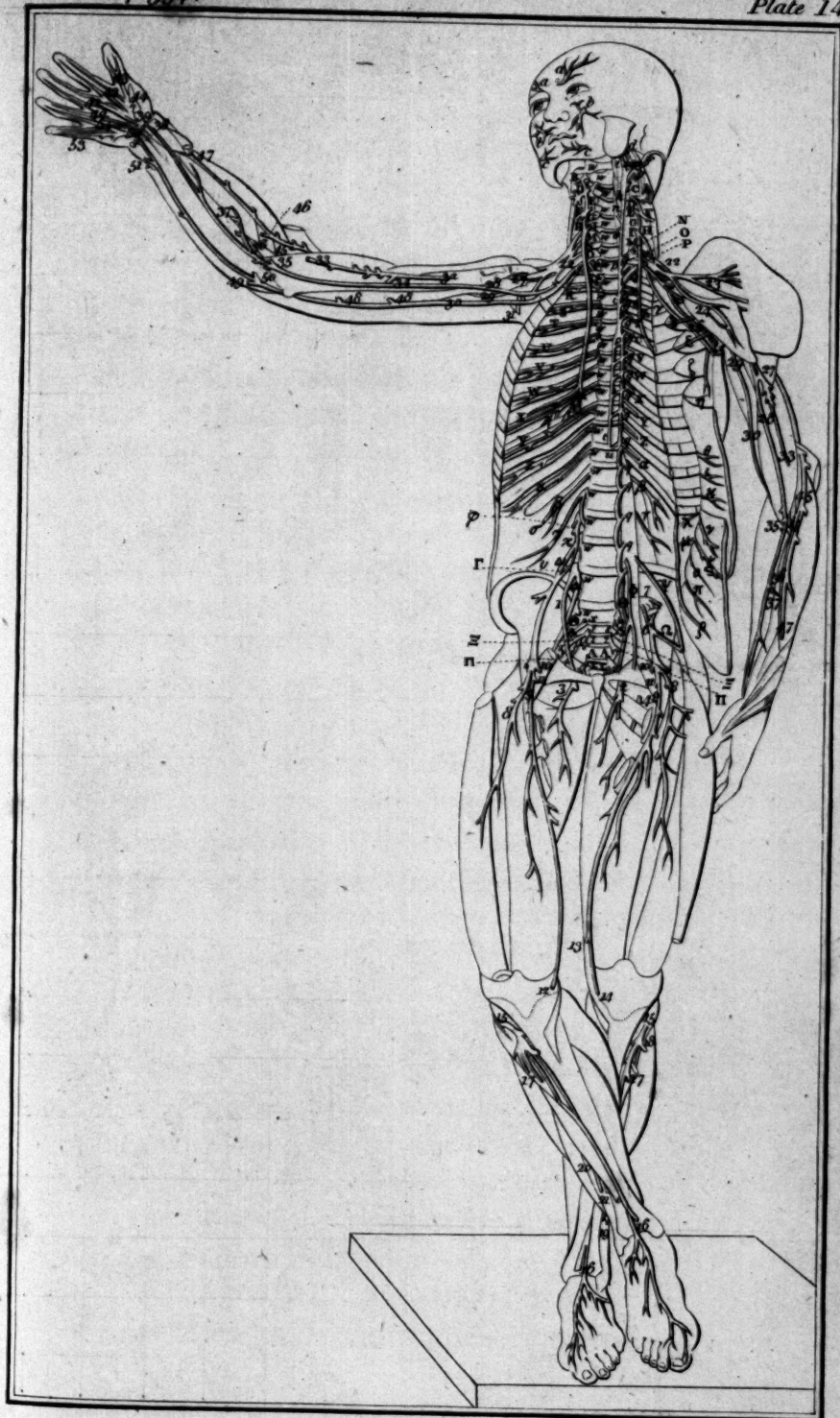
14, The

- 14, The internal branch of the left crural nerve cut off.
- 15, 15, Branches of the sciatic nerves. They produce the branches, 17, 17, 18, 19, 20, 21 : of which 17, 17, belong to the long extensors of the toes ; 18, to the peroneus longus ; 19 is subcutaneous, and divides itself into two branches, which answer to the branches 20 and 21 ; 20, 21, are a variation of the branch 19, dividing itself sooner into 20, 21.
- 22, 22, The fifth, sixth, seventh, and eighth pair of cervical nerves.
- 23, A branch, which, arising from the above nerves in their course to the axilla, is distributed to the inside of the pectoral muscle.
- 24, A branch, which, arising in the same manner from the above nerves, is bestowed upon the inside of the serratus anticus.
- 25, 25, A branch, which, going off like the former from the above nerves, belongs to the muscle called latissimus dorsi.
- 26, A branch of the sixth pair of cervical nerves, bestowed upon the serratus magnus muscle, running down according to the direction of that muscle, and afterwards under the latissimus dorsi.
- 27, 28, 29, 30 ; 27, 28, 29, 30. The four large brachial nerves, in which those running on each side by the axillæ principally terminate : 27, 27, The first, which in a manner perforate the muscoli coracobrachiales. 28, 28, The second, which run according to the length of the humerus as far as the bending of the arm,

- arm, and from thence by the fore-arm, down to the palm of the hand. 29, 29, The third, which run on the back part of the humeri.
- 30, 30, The fourth, which run down, according to the length of the humerus, to the posterior part of the large condyle, and from thence by the fore-arm to the palm of the hand.
- 31, A branch of the third brachial nerve 29.
- 32, The first of the brachial nerves 27, after it has run a little way under the coracobrachialis muscle, makes it way through it, and afterwards runs under the shorter head of the biceps, giving branches to this, and the internal brachial muscle; it is cut off, at 33.
- 34, A branch of the first of the brachial nerves, which it sends off to join the second. The same in the left arm.
- 35, 35, Here the second trunks of the brachial nerves 28, 28, give branches to the pronatores and teretes, the radiales interni, the sublimes, and palmares longi muscles.
- 36, 36, Considerable branches of the second brachial nerves, which send off branches to the profundus, and the long flexors of the thumbs; and afterwards 37, 37, get in between these muscles, and run down to the pronatores quadrati muscles.
- 37, This second of the brachial nerves, passes through the ligament of the wrist on the inside; afterwards, 39 proceeds to the wrist, where it divides itself into five branches, 40, 41, 42, 43, 44. Of which

40, The

- 40, The first, gives a branch to the third lumbrical muscle, after which it divides itself into two; one branch running along the side of the ring finger next the middle finger, and the other along the side of the middle finger next to the ring finger.
- 41, The second, gives a branch to the second lumbrical, and afterwards divides likewise into two; one branch running along the side of the middle finger next the fore finger, and the other along the side of the fore finger next the middle finger.
- 42, The third, gives a branch to the first lumbrical, and afterwards runs upon the side of the fore finger next the thumb.
- 43, The fourth, goes to the thumb, and, there dividing into two, runs upon each side of it.
- 44, The fifth, which is here cut off, gives a branch to the short abductor of the thumb. And then it gets between the short flexor and the musculus opponens of the thumb, and belongs to the opponens.
- 45, 45, Continuations of the brachial nerves. The third pair of brachials 29, 29, after having run backwards by the shoulder-bones from the axillæ, and then between the external brachial muscles on the one side, and the long and short heads of the bicipites on the other, and afterwards between the internal brachials and long supinators, emerge here 45, 45, between these last-mentioned muscles, and thence proceed to the inside of the fore-arm, where having given off branches to the long supinators



nators and external radial muscles, they pass through the short supinators 46, 46.

47, 47, Nerves cut off.

48, 48, Branches of the fourth brachial nerve 30, going to the external brachial muscle 49, 49, to the internal ulnar, 50, to the profundus.

51, A branch of the same, which passes under the internal ulnar to the back part of the extremity of the fore-arm, and makes a subcutaneous nerve.

After giving off this branch, the fourth brachial nerve runs before the ligament of the wrist inwards, towards the palm of the hand, where it divides into the branches 52, 53, 54. Of which

52, The first remarkable one, spreading itself in the wrist under the tendons of the profundus and the lumbricales muscles, its branches are distributed principally to these, viz. the abductor of the little finger, the adductor of the fourth metacarpal bone, the interosseous muscles, the adductor of the thumb, the short flexor of the thumb, and the abductor of the fore finger.

53, The second, after it has given off the subcutaneous branch which is here cut away, and another to the abductor of the little finger, runs along the back part of the little finger.

54, The third, dividing into two at the roots of the ring finger and little finger; one branch runs along the side of the little finger next the ring finger, and the other along the side of the ring finger next the little finger.

CHAP. XXIX.

CIRCULATION OF THE BLOOD.

*Structure of the Heart, and circulation in cold-blooded Animals.—
Circulation in the warm-blooded Animals.—Course of the Blood
through the Lungs.—Through the rest of the Body.—Ramifica-
tions of Arteries.—Valvular structure of Veins.—Different from
the structure of Lymphatics.*

THE structure and uses of the organs concerned in the circulation of the blood have been already considered, and it was farther remarked that the heart of man is of a duplex construction, in other words, that it has *two* auricles and *two* ventricles. With a view to perspicuity, before we proceed to the circulation in the human body, it will be necessary to mention the structure of the heart in certain animals in which it is more simple.

In frogs, serpents, and other cold-blooded animals, the heart consists of only two cavities, an auricle and a ventricle; from the auricle the blood passes into the ventricle, from the ventricle it is driven into the arteries, from the arteries it is received into the veins, and by the veins is again brought back to the auricle.

This being well understood, it cannot be difficult to comprehend the course of the circulation in man, and the warm-blooded animals, in which the only difference is, that the heart being double, or con-
sisting

sisting of four cavities, the blood performs two circles instead of one. From the anterior auricle the blood passes into the anterior ventricle; from the anterior ventricle it is conducted by the pulmonary artery to the lungs, and from the lungs, the pulmonary veins bring it back to the posterior auricle; from the posterior auricle it passes into the posterior ventricle; from the posterior ventricle it is carried to every part of the body, by means of the aorta and its branches, and thence is again brought back by the *venæ cavæ* to the anterior auricle, whence it proceeded. In this manner, throughout life, the blood is constantly performing two circles; a lesser between the heart and the lungs, and a larger between the heart and the rest of the body.

The two auricles and ventricles are of equal capacity, and correspond in their contractions. From these circumstances it is evident, that the same quantity of blood passes through the lungs in a given time, as through all the rest of the body, and, consequently, that the circulation must be much more rapid in the lungs than in other parts. It is supposed that about two ounces of blood are thrown from each ventricle of the heart at every contraction.

The heart, however, though the most remarkable, is not the only organ of circulation; since every vessel through which the blood passes assists, by its contractile powers, to propel its contents. The sudden contractions of the heart, by which the blood is thrown into the arteries, occasion their pulsation, which is most violent in the large trunks, gradually becomes less remarkable as they ramify and recede

from the heart, and is not at all perceptible in the veins, which receive their blood from the arteries. The contraction of the ventricles, by which the blood is propelled from the heart, is called the systole; the dilatation, by which the blood is received into them, the diastole.

The structure of the heart in the tortoise and some other amphibious animals is intermediate between that of cold-blooded animals and warm-blooded.

The heart has two distinct auricles, without any communication: and under these, there is the appearance of two ventricles similar in shape to those of the latter class: but they may be considered as one cavity; for the ventricle sends out not only the pulmonary artery, but likewise the aorta; for there is a passage in the septum, by which the ventricles communicate freely, and the blood passes from the left into the right one. From the aorta the blood returns into the right auricle, while that from the pulmonary artery returns to the left auricle, from which it is sent to the left ventricle, &c. so that only a part of the blood is sent to the lungs, the rest going immediately into the aorta; hence the animal is not under the necessity of breathing so often as otherwise it would be.

The ends of the arteries are the beginnings of the veins, which uniting, as the arteries divided, at length form large trunks, which generally correspond with the trunks of the arteries, from which, by the medium of smaller branches, they received their contents.

But

But though all arteries terminate in veins, yet the minuteness of their ramifications, before this takes place, is various; while some transmit the red globules, others exclude them, and transmit nothing but serum.

A circumstance contributing greatly to the progress of the blood in the veins is their valvular structure, fitting them for deriving assistance from pressure; and we find accordingly in the limbs, and wherever else any advantage could be obtained from this circumstance, that the veins are furnished with valves, while in the cavities of the body, where they are not so much pressed by the action of muscles, this part of their structure is wanting.

The motion of the fluids of the valvular lymphatic system is quite distinct from the circulation of the blood. These vessels begin by open mouths, which perform the office of absorption, and their contents are not derived, like those of the red veins, from the extremities of arteries; their fluids are therefore propelled, without any aid from the heart, by their own contractile powers.

The most remarkable functions, to which the circulation of the blood is subservient, are secretion, the nourishment of the body, and certain changes which the blood undergoes in its passage through the lungs; of these it will be proper to treat in the chapters immediately succeeding.

C H A P. XXX.

SECRETION, EXCRETION, ABSORPTION, AND
NOURISHMENT.

General Effects of Secretion.—The Glands.—Excretion.—Secretion of Bile.—How this Function is performed in Fishes.—Absorption.—Lymphatic Glands.—Nourishment or Reparation of the Body.—Bones become more solid in old Age.

THERE is no function of the body which is more calculated to excite our astonishment and admiration, than that of secretion. By secretion we see one fluid, the blood, modified more variously and more exquisitely than the human mind can easily conceive, or ever hope to explain; in one part, secreted fluids, varying in different races of animals according to their food, are endued with a power of dissolving the aliment, and fitting it for the nourishment of the body; in other parts, secretion furnishes fluids for lubricating the organs concerned in the various functions of the animal machine. In some animals the most powerful odours, in many the most deadly poisons, and in all, that wonderful fluid by which their race is perpetuated, are the products of secretion.

So far are we from discovering the nature of secretion, and the causes of the different properties of the fluids which are secreted, that we in reality know little more of this function, than the general outlines of the structure of the parts concerned in it. We see a gland, with an artery, vein, and excretory

cretory duct connected to it, but whether the secreted fluid is formed by exudation through the coats of the minute arteries distributed in the gland, or whether it is poured out from the open extremities of arteries into small receptacles, and is thence received into the excretory duct, or in what other mode the change wrought on the blood conveyed to the gland is effected, we are entirely ignorant. So different, however, are the properties of secreted fluids from those of the blood, that it is probable something more happens than a mere separation of principles, which previously existed in that fluid.

By some physiologists it has been imagined, that secretion may be explained on the simple supposition of a difference of diameter in the vessels from which the secreted fluids are poured out. On this idea it has been advanced, that the thinnest fluids are formed by the arteries of the smallest diameter, and the more dense by arteries of a larger size; but it is evident, that though the smaller arteries would exclude the larger particles, still the larger arteries would suffer the smaller particles to pass through them, and thus the secretion be in some measure confounded.

Excretion, like secretion, is performed in general by arteries. The term secretion is applied to the formation of those fluids which are subservient to some purpose in the animal machine; that of excretion to the formation of such as are apparently of no particular use, and which seem to be separated for no other end than to be discharged from the body. It is difficult, however, to apply these dis-

tinctions to particular cases, since there is hardly any one of these fluids, the production of which is not in some way useful, and but very few which may not be considered as in some degree excrementitious.

Both secretion and excretion are in many parts of the body performed by the minute ramifications of arteries opening on the surface of membranes, without the intervention of glands. Fluids, which are designed for the lubrication of passages, are very generally discharged into small bags or follicles, whence they are expressed, when their presence is most necessary.

Few of the secreted fluids are discharged from the body exactly in the state in which they were first prepared, but gradually become more viscid or acrid; since, while they remain in the receptacles destined for their preservation, their more watery parts are continually taken away by the action of the absorbents.

We have hitherto considered secretion to be on every occasion the work of arteries, but it is now necessary to take notice of a remarkable exception to this rule, and to inform the reader, that the most copious secretion in the body is performed by veins. The blood, which is carried by the arteries to the body at large, is generally returned by the readiest passages to the heart; but it is ordered otherwise with respect to that which is sent to the bowels.

The blood from the abdominal viscera is received by a large vein, furnished with remarkably dense coats, and called, from entering the liver as through a gate, the *vena portarum*; this vein is distributed

tributed through the substance of the liver, in the same manner as arteries are distributed through other glands.

The liver, however, is furnished with an artery which may possibly have some influence in the preparation of the bile. The ramifications of this artery inosculate with those of the vena portarum, and the blood from both is returned together to the heart, by veins which empty themselves into the vena cava.

A fact so contradictory to the analogy of the other secretions cannot fail to excite our wonder and curiosity. Our curiosity we cannot hope to gratify, since the present state of our knowledge, with respect to the nature of secretion, gives us little room to expect a discovery of the advantages which are derived from this or any other peculiarity in our frame; but our wonder will be lessened by considering, that the same peculiarity takes place in certain animals, under circumstances still more remarkable. In fishes, a single artery arises from the ventricle of the heart, which is entirely distributed on the gills; from the gills the blood is gradually collected into a large vessel, corresponding to the aorta in man, and distributing the blood to every part of the body. From the bowels, however, the vessels still again unite, and form a large trunk, which, entering the liver, performs the secretion of the bile, in the third circle of the blood, since it passed through the heart; whereas in man the blood, in passing through the liver, is only in its second circle or course,

Absorption, as was before remarked, is performed by a system of vessels quite distinct from those concerned in the circulation of the blood. Their appearance, structure, and course through the body, have been already described. The uses of the absorbents in the animal œconomy are of the most important nature. By the absorbents all the nourishment of the body is conveyed from the intestines towards the heart; and by the absorbents those particles, which have become useless in any of the organs, are taken up, conveyed into the mass of circulating fluids, and ultimately discharged from the body. The bones themselves afford evidence of the action of the absorbents, as their component particles are continually changing throughout life, and as all the bones lose considerably of their weight in extreme old age.

At the same time, however, that their actual weight is lessened, their specific gravity is increased; for the bones of old people are thinner and more compact in their sides, and have larger cavities. By chemical analysis, the proportion of earth is found to be increased in the progress of life.

The absorbents are particularly numerous in glands, and very probably have their influence in producing the phenomena of secretion. The fluids, which are secreted, for lubricating the joints and muscles, and for moistening the several cavities of the body, are continually renovated by the absorbents, which take up what is already effused, while more is supplied by the arteries,

The uses of the glands connected with the lymphatic vessels are not well understood, but from
their

their being universal, and from our not being able to find a single lymphatic vessel, which does not, in its progress towards the heart, pass through some of them, it may be concluded that their uses are very important. One of the purposes, however, which they serve, is, probably, to prevent any thing injurious, which may be taken up by the absorbents, from entering the mass of blood; and in this way the minute ramifications, into which the lymphatics are divided in their passage through these glands, may perform the office of a filter. There are several arguments which might lead us to believe, that the lymphatic glands belonging to the lacteals have some share in digestion, or for fitting the chyle for entering the mass of circulating fluids; but their influence in this respect is not proved, nor does it seem easy to ascertain it. Several hypotheses have been formed by ingenious men, with a view to explain the mode in which the absorbents act in taking in their contents; but as they are but hypotheses, I shall pass them over in silence.

As the absorbents are continually taking away the substance of the body, it was necessary that there should be organs, which, by furnishing fresh particles, might counterbalance their effects; and these organs are the arteries. It has been already observed that the arteries, for an important purpose, convey the blood to every part of the system; by means of the blood, however, the arteries not only produce the secretions, but furnish matter to every exhausted organ of the body; and from one fluid, restore the lost particles of the bones, the muscles,
and

and the nerves, or whatever other solids stand in need of repair.

This office, however, of the arteries, pre-supposes that there must be a source, from which they are themselves supplied with the substance they furnish to the other organs; and this leads to the consideration of the important function of digestion.

CHAP. XXXI.

DIGESTION.

Sensations of Hunger and Thirst.—Progress of the Food to the Stomach.—Digestion, how performed by Men and Quadrupeds.—By Birds.—The Gizzard of Fowls, and its Uses.—Birds of Prey.—Reaumur's Experiments on the Digestion of Fowls.—Motion of the Stomach and Gizzard.—Balls of Hair found in the Stomachs of Quadrupeds.—Gastric Fluid.—Stomach itself partly dissolved by its Action after Death.—Fermentation only takes place in diseased Stomachs.—What Substances are digestible, and the contrary.—Powers of Digestion in different Animals.—Carnivorous.—Granivorous.—Gramenivorous.—Sleeping Animals.—Accommodating Power of the Stomach.

ANIMALS are powerfully admonished to repair the waste of their bodies by an aversion from the sensations of hunger and thirst, and a desire of that pleasure which attends the gratification of these appetites. Solid food, being taken into the mouth, is masticated by the teeth, and mixed with saliva and mucus, which, by the pressure and action of the parts, are very copiously exuded. Thus softened and lubricated, the food is conveyed to the root of the tongue, and the lower jaw being now fixed by the shutting of the mouth, we are prepared to act with the muscles which pass from the bone of the lower jaw to that which supports the tongue, called the os hyoides. A convulsive action of these muscles suddenly draws forwards the os hyoides, the root of the tongue, and the larynx; the pharynx is enlarged, the food is forced into the gullet, and in its

6

passage

passage presses down the epiglottis, so as to prevent any thing from getting into the windpipe. The parts before thrown into action are now relaxed; the food is received by the gullet, and is regularly but rapidly conveyed to the stomach. Fluids are conveyed to the stomach in the same manner as solids. So perfect and exact is the action of the gullet in propelling its contents, that even air cannot elude its grasp, which is proved by our having the power of swallowing air, by taking a mouthful of it, and using the same efforts which we employ in swallowing our food.

After the food has reached the stomach, it is still further softened, and at length reduced to a pulpy consistence, by means which we shall presently examine. It now passes through the pylorus, or right orifice of the stomach, into the duodenum, where it is retained for some time, and attenuated by the admixture of the bile from the liver, and the pancreatic juice from the pancreas. From the duodenum it passes into the jejunum and ileum, in which it is moved backwards and forwards by the muscular contraction of their coats, called their peristaltic motion. As it proceeds, its more fluid parts are continually taken up by the lacteals, and it consequently gradually becomes of a thicker consistence. From the small intestines it passes through the valve of the colon into the large. Here it probably undergoes still further changes, and more of its fluid parts are absorbed by the lacteals. It is at length received by the end of the intestinal tube, called the rectum, and being of no further use, is discharged from the body.

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The chyle, which is the product of the digested aliment, after it enters the lymphatics, is conveyed to the heart, and mixed with the mass of blood. Let us now examine the instruments, which nature employs in so wonderful a process, as that of fitting dead matter for receiving active properties, and being endued with life.

‘A great many substances may enter the lacteals along with the chyle, even solids reduced to fine powder. When indigo has been thrown into the intestine of a sheep, I have seen the chyle rendered quite blue: now indigo is not soluble in water, but is a solid reduced into a very fine powder. So musk gets into the chyle, giving it a strong smell, and a great variety of other substances of various colours, various tastes, and various smells, each of them giving colour, or taste, or smell, to the chyle. Nevertheless the lacteals seem to possess some power of rejection, since green vitriol, either exhibited along with the food, or thrown into the intestine after the animal has been opened, while chyle was forming and absorbing, gives no colour on infusion of gall being applied to the chyle; nor if galls are thrown into the stomach along with the food, or if an infusion of them is in like manner thrown into the intestine, when an animal is opened, during the time that the chyle is flowing into the lacteals, do they give any colour upon a solution of green vitriol being applied to the chyle*.’

Dr. Fordyce mentions several instances of the strong assimilating powers of the stomachs of certain animals; such as fish thriving, increasing in size, and excluding feculent matter when confined in

* Fordyce on Digestion, p. 122.

spring water, without any perceptible source of nourishment, and even when a communication with the air was cut off. He also remarks, that not only farinaceous and other bland substances are found to be attacked by insects, but also jalap, scammony, hemlock, and the most deadly vegetable poisons. Even cantharides are greedily devoured by two species of insects, not part of them picked out from other parts, but the whole entirely, without leaving a vestige of any the least part of the cantharis undevoured. Dr. Fordyce has procured these insects from chests of cantharides imported from Sicily, and which had lived upon the cantharis for several months. After being washed with water slightly, these insects have juices perfectly bland, so that if they are bruised and applied to any the most tender and sensible surface of the human body, they produce no inflammation, nor is there any appearance of their possessing any matter having a stimulating quality.

There are two different processes, which in general seem essential to digestion; viz. trituration and the action of a certain fluid or menstruum. All quadrupeds are furnished with teeth, by which they in some measure destroy the texture of their food before it passes into the stomach. The instrument of trituration in granivorous fowls, and which answers the purposes of the teeth of quadrupeds, is the gizzard, through which all their food passes, before it enters the organ, which may properly be denominated their stomach. Among fowls, however, there are some which have a stomach purely membranous, as the eagle, the hawk, and

and birds of prey in general. These have neither gizzard nor teeth, but they are furnished with a sharp and crooked beak, which, by tearing their food to pieces, serves in some measure to prepare it for the action of the other instrument of digestion, a fluid endued with peculiar qualities, and which, as far as our observations extend, seems to be in common to all animals.

The gizzard is an organ composed of very thick and strong muscles; it is lined internally with a substance so thick and callous as not to be hurt by grinding down glass, and which is always found to contain small stones of the hardest materials the bird can procure. By the help of these stones, and by means of the hard internal coat of the gizzard, and the force of its muscular coat, the food is effectually ground down, and fitted for entering the stomach.

Spalanzani, and others, have denied (says For-dyce) that they were of this use, and have affirmed that the stones were picked up by mere accident, the animals mistaking them for seeds. But I have examined this particularly in experiments I made in hatching eggs with artificial heat; I have hatched vast numbers, and frequently have given the chickens small seeds whole, taking care that they should have no stones. In this case the seed was hardly digested, and many of the chickens died. With the same treatment in every respect, others who had their seeds ground, or have been allowed to pick up stones, have none of them been lost. With tolerable care, when common chickens are once hatched by artificial heat, they are easily brought up without a hen, as by instinct they will keep in that part of the furnace
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where there is the proper degree of heat, and the proper exposure to air. Instinct also teaches them what substances they should choose for food, and what quantity of stones it is necessary to intermix with it. For if a very large quantity of small stones is mixed with a small proportion of grain, they will pick out the grain, so that the proportion of stones which they swallow shall be very little, if at all greater than when only a few were intermixed. In those I examined the proportion of stones were not at all greater when there was a large quantity of them mixed with the grain, than when there was a small proportion; and I have often observed them choosing one piece of stone, and rejecting another. Birds have also an evident instinct even to distinguish one kind of earth from another, as may easily be seen in Canary birds; the hen, at the time of her laying her eggs, requires a quantity of calcareous earth, otherwise she is frequently killed by the eggs not passing forward properly, as I have in many instances observed; to one set of hens a piece of old mortar was given, which they broke down and swallowed, certainly not mistaking it for Canary seed, or any kind of food, but distinguishing it from a piece of brick, which they did not either break down or swallow; another set at the same time were kept without any calcareous earth; many of these died, while the others, although otherwise exactly in the same circumstances, were none of them lost. It appears therefore that birds have a necessity for stones being swallowed for digestion, and earths for other purposes, and that they have an instinct which disposes them to choose the proper quantity

quantity and quality required. Moreover, as Mr. Hunter observes, the noise of the grinding may be heard, and therefore there can be no doubt that this stomach is made to contain stones for the same purposes for which teeth are employed *.

The lobster is furnished, for the comminution of its food, with an apparatus which is situated at the pylorus. It consists of two bony surfaces, formed into ridges, which are applied to each other like those of the molares. They are also covered, like our teeth, with enamel, and furnished with muscles, by which the action of grinding is performed.

In order to discover the power of the gizzard, Reaumur gave to a turkey small tubes of glass, five lines in length and four in diameter; these were broken in the gizzard in twenty-four hours. In the place of glass tubes he substituted tubes of tinned iron, seven lines in length and two in diameter, closed with solder at each end. Some of these were indented by the action of the gizzard, and others crushed quite flat. Similar tubes, placed between the teeth of a vice, required a force of four hundred and thirty-six pounds and a half to produce the same effects.

Inclosing in tin tubes, properly perforated, some grains of barley, some unboiled, some boiled, and others peeled, and letting them remain a day or two in the stomach, he found them only a little swelled. The same experiment being tried with meal, the same consequences were observed, as it did not become in the smallest degree putrid. From these experiments Reaumur concluded, that digestion, in

* Fordyce on Digestion, p. 24, &c.

birds provided with a gizzard, was chiefly performed by means of trituration.

Such are the powers of the gizzard; but those of the membranous stomach, though of a very different nature, are not less astonishing. It is well known that birds of prey, which swallow every part of the animal they devour without much distinction, have the power of throwing up such parts of their food as they cannot digest. Taking advantage of this circumstance, the same naturalist gave tubes, similar to those above mentioned, and filled with flesh, to a buzzard hawk; in twenty-four hours the tubes being thrown up, the meat which they contained was reduced to an oily pulp, and with no appearance of putridity. At the end of forty-eight hours, the decomposition was still more perfect, the pulp was more attenuated and blanched, and that constantly without any smell. The tubes being filled with the bones of young pigeons, instead of butcher's meat, these were converted into a jelly in twenty-four hours. Beef bones, very hard, and deprived both of flesh and marrow, out of forty grains lost eight in twenty-four hours, and in three days were totally dissolved. Grain and fruit exposed to the same process, were very little if at all affected. Digestion, therefore, in birds of prey is performed by a fluid, which acts only upon animal matter. This fluid is very abundant in the stomachs of these animals. Small pieces of sponge, of thirteen grains, shut up in the tubes, weighed three grains more when thrown up.

Notwithstanding these effects of the digestive organs, the motions of the stomach and the gizzard are scarcely perceptible. There is reason, however,
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to believe that the little motion they have is very regular. On examining the surface of the balls of hair which are found in the stomachs of animals which lick their coats, the hairs in each hemisphere seem to arise from a centre, and to have the same direction, which is circular, and corresponding with what would appear to be the axis of motion. This regularity in the direction of the hair could not be produced if there was not a regularity in the motion of the stomach. The same is proved in some birds, as the cuckow, which sometimes feeds on hairy caterpillars.

The principal instrument of digestion in most animals, is however now generally supposed to be the gastric juice; a fluid which distils from certain glands, situated in the coats of the stomach, and mixes with the food as soon as it is received into it.

The Abbe Spalanzani, in order to obtain a sight of the gastric juice, introduced tubes, containing bits of sponge, into the stomach of a crow. In four hours the tubes were vomited up, and the sponges, being pressed, yielded thirty-seven grains of gastric liquor, which was frothy, of a turbid yellow colour, had a taste intermediate between bitter and salt, and being set to stand in a watch glass, deposited in a few hours a copious sediment. As the sediment might be attributed to the food suspended in the gastric juice, the experiment was repeated on a crow, the stomach of which was empty. The fluid obtained in this case was of a transparent yellow colour, deposited very little sediment, but the taste was the same. The gastric juice did not burn

when thrown on hot coals, and paper moistened with it would not burn till the fluid was evaporated.

The motion of the stomach also assists in mixing and intimately blending this fluid with the proper parts of the aliment, so as to enable its solvent powers more completely to act upon it. The sensible qualities of this fluid are, however, not such as to lead us to attribute to it any such power; and I do not know that it has been completely analyzed by any chemical process, at least by any which enables us to explain its solvent property. A French * author indeed, observing the power which inflammable air has in dissolving the texture of animal matter, has intimated an opinion, that a portion of the oily matter which is taken in with the food, may be modified by the stomach into inflammable air, and may perform this part of the process of digestion.

Digestion differs from all other processes, and can be compared neither to putrefaction nor chemical solution. A remarkable circumstance also with regard to digestion is, that by it both animal and vegetable matter is converted into the same substance.

Dr. Fordyce fed a dog with farinaceous matter, and another with muscle, and opening them both (in which he does not appear to have been justifiable) during the time that the chyle was flowing through the lacteals, he collected from each as much chyle as he was able. On examination they

* M. Sage.

were found so similar, that the difference could not be distinguished by any experiment which he could contrive. The chyle of a cat living on flesh, according to the same gentleman, cannot be distinguished from that of an ox or sheep.

Live or fresh vegetables, when taken into the stomach, are first killed, by which a flabbiness of texture is produced, as if they had been boiled, and then they begin to be acted on by the gastric juice. This fluid indeed, seems to have no power to act on living matter, since worms remain uninjured in the stomach. Digestion, however, as far as relates to the dissolution of aliment, may be carried on out of the body by means of the gastric juice, and the application of heat equal to that of the human body. This process is continued after death, and the stomach, no longer protected by the living principle, is itself dissolved by the gastric juice.

In the stomachs of large fish are commonly found small fishes, still retaining their natural form; but when touched, they melt down into a jelly. From this circumstance, and from the great quantity of fluids poured into their stomachs, we may conclude, that digestion is solely effected in them by the dissolving power of a menstruum, without the aid of trituration.

Neither animal nor vegetable substances can undergo their spontaneous changes, while digestion is going on in them. The gastric juice even has a power of recovering meat already putrid; for let putrid meat be given to a dog; and the contents of his stomach will be found sweet, and free from all putrefaction, if he is killed a short time after.

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Bread, which has remained in the stomach of a dog for eight hours, is so much changed, that it will not run into the vinous fermentation, but when taken out and kept in a warm place becomes putrid. Its putrefaction, however, is not so quick as that of a solution of meat which has been in the stomach for some time. The effects are similar when milk and bread are the food.

When the digestive power, however, is not perfect, then the vinous and acetous fermentation will take place in vegetable matters, and the putrefactive in the stomachs of animals which live wholly on flesh. The gastric juice apparently preserves vegetables from running into fermentation, and animal substances from putrefaction, not from an antiseptic quality in that fluid, but from a power of making them go through another process. In most stomachs there is an acid, even though the animal has lived entirely upon meat for many weeks; this, however, is not always the case. The acid sometimes prevails so much as to become a disease.

The stomachs of many animals have a power of coagulating milk; this is continually seen by infants throwing up their milk in a coagulated state, and the same thing may be observed by feeding a dog with milk, and killing him half an hour afterwards. The stomach of the calf, and perhaps that of other animals, preserves this power after death, and is kept dried, for the purpose of making cheese. Indeed milk, raw egg, and several other substances, require to be coagulated, before they can be digested.

If we throw milk into a portion of the jejunum, that milk will be absorbed by the lacteals; but if we throw milk into the stomach of the same animal, the milk will not be absorbed by the lymphatics; therefore an argument might be brought, that the absorbents of the stomach would refuse what the absorbents of the jejunum would readily take up. But it must be considered that the milk is instantly coagulated in the stomach, and not in the jejunum, which coagulation will perfectly prevent it from being absorbed; but all those substances which are not changed by the coagulating juice of the stomach will be, and are equally taken up by the lymphatics in the stomach and lacteals. There is, therefore, a conversion of the food in the stomach into a new substance, whose properties are at present unknown, which new substance is the only one which can be converted into chyle in the duodenum and jejunum, exactly as we may form farinaceous matter, mucilage, native vegetable acid into wine; but before they can possibly be converted into wine, they must first be formed into sugar. So in a similar manner farinaceous matter, gum, and white of egg, are all capable of forming chyle; but before they are formed into chyle, they must be converted into a matter certainly not sugar, but a matter of a particular species in the stomach, and by the operation of the stomach, this particular species of matter is afterwards converted into chyle in the duodenum and jejunum.

Dr. Young, of Edinburgh, found that an infusion of the inner coat of the stomach, which had been previously washed with water, and then with dilute

solution of mild fixed vegetable alkali, so that it was not possible that any acid could have remained in it, coagulated milk very readily. He found also that it had the power of coagulating serum, and other animal mucilages. The coagulating power of this substance is very great. Dr. Fordyce mentions that six or seven grains of the inner coat of the stomach infused in water, gave a liquor which coagulated more than a hundred ounces of milk.

All fermentation is quite foreign from perfect digestion, and when it does take place, is always proportioned to the disorder of the stomach, since very little if any wind or flatulency is generated in the stomachs of those, whose digestion is most quick and easy. It is not uncommon, however, for milk, vegetables, wine, and whatever has sugar in its composition, to become sooner sour in some stomachs than if left to undergo a spontaneous change out of the body; and even spirits, in certain stomachs, almost immediately degenerate into a very strong acid. All oily substances, particularly butter, become rancid very soon after being taken into the stomach, and this rancidity is the first process in the fermentation of oil. Animal food does not so readily ferment in diseased stomachs, when combined with vegetables, as when it is not. Flesh meat appears to undergo no change preparatory to digestion, but seems at once to submit to the action of the gastric juice. It appears first to lose its texture, then becomes of a cineritious colour, next gelatinous, and lastly, is converted into chyle.

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In order to ascertain whether the production of any degree of acidity is essential to digestion, Dr. Fordyce made several experiments, from which he concludes, that in perfect digestion no acidity whatever is produced.

If the gastric juice is applied to a substance out of the body, in a proper temperature, it will produce changes in it, similar to those which take place in the commencement of digestion; but by applying gastric juice, the watery fluids of the stomach, the saliva, the bile, the pancreatic juice, altogether or separately, in no case has chyle, or any thing like it, been formed.

It is not yet ascertained what are the circumstances which contribute to render different articles used as food, digestible or indigestible. Something is undoubtedly to be ascribed to firmness of texture, since cuticle, horn, hair and feathers, which are indigestible in their natural state, became digestible and nutritious when reduced to a gelatinous form by Papin's digester. That the solubility or insolubility of a substance in the stomach is not, however, merely owing to the degree of solidity, is proved from a circumstance already mentioned, viz. that boiled barley was not acted on by the gastric juice of a buzzard hawk, while pieces of hard beef bone, exposed to its action in the same manner, were completely dissolved. But substances may even be rendered too soft; for a fluid is difficult of digestion, and its continued use very injurious to the stomach. It may be remarked, that nature has given us very few fluids as articles of food. It therefore seems, that substances may be either too compact or too
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lax in their structure, to render them fit subjects to be acted on by the digestive powers.

The degree of ease, however, with which substances are digested, seems in many cases owing to a difference in solidity. Brain, liver, muscle and tendon are digestible in the order in which they are here put down. Boiled, roasted, and even putrid meat is easier of digestion than raw. Husks of seeds and the hulls of fruits are indigestible in their natural state, but to what circumstance this is owing is not fully ascertained. The whole of our food is sometimes not digested; this may arise from two causes, either from some parts of the food being of too firm a texture to be dissolved so soon as the other parts are converted into chyle and carried into the duodenum: or from the stomach being so much disordered as to digest imperfectly. This disorder of the stomach sometimes proceeds so far, that the food passes through the body almost unchanged. In some cases food has been retained on the stomach for twenty-four hours, and thrown up without being altered in the least.

The essential oils of animals and vegetables are indigestible; they are soluble, however, either in the gastric juice or the chyle, by which means they become medicinal from their stimulant powers. The essential oils of vegetables, but more particularly those of animals, seem to pervade the very substance of the animals whose food contains much of them. Thus sea birds, which feed on fish, taste very strongly of them, and those which live on that food only during certain times of the year, as the wild duck, have that taste only at certain seasons.

Two ducks were fed, one with barley, the other with sprats for about a month, and killed both at the same time; when dressed, that fed on sprats was hardly eatable.

Animals eat less in proportion as their food is more nutritious. Thus carnivorous animals require much less food than the granivorous, and these, than the graminivorous; animals, indeed, of the last kind, employ almost the whole of their time in eating. A corresponding relation is also observed with respect to the digestive organs in these several races of animals; carnivorous animals have only one stomach, granivorous animals very generally two, and graminivorous animals four stomachs, with a greater length of intestines. From which circumstances it may be collected, that grass is more difficultly assimilated than grain, and grain than flesh.

The first stomach in ruminant animals, such as the bull, the sheep, &c. is a receptacle which has a very weak action on the food, and from it the animal has the power of returning the food into the mouth, to undergo a second mastication. In Mr. Hunter's paper on Digestion, published by the Royal Society, there is the following curious observation, which illustrates very much the use of these previous stomachs: milk sucked in by the calf does not remain in any of the previous stomachs; but passes down instantly into the digesting stomach, not requiring any previous operation; but grass remains for a length of time in the previous stomachs.

If it is allowable to extend our views beyond the animal kingdom, we might fancy that the digestive process in vegetables is still more difficult than it is

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in the graminivorous animals, since vegetables are continually taking in nourishment, and consume an immense quantity of air and water in proportion to their growth and bulk. When vegetables, however, are furnished with matter which has undergone more preparation than mere air and water, viz. putrified vegetable matter, their growth is far more rapid; and they flourish still more on the remains of the animal kingdom.

Sleeping animals do not digest during winter. Worms and pieces of meat were conveyed down the throats of lizards, which were going into winter quarters, and which were afterwards kept in a cool place. On opening the animals at different periods, the substances were found entire and without alteration. Some of the lizards voided them in the spring with little or no alteration produced in them. Digestion is therefore regulated by the state of the other functions of the body*.

By hunger and custom animals may be taught to eat, and even to prefer, a very different kind of food from that naturally designed for their nourishment: thus pigeons have been made to live entirely on flesh. Whether the gastric juice is altered in its nature by a difference of food, or in what other way the system accommodates itself to such a change, it is not easy to determine.

* Hunter on Digestion.—See his volume on the Animal Economy.

C H A P. XXXII.

RESPIRATION AND ANIMAL HEAT.

Respiration in part an involuntary Function.—Four Stages of Respiration.—Uses of Respiration.—Respiration of Insects different from that of other Animals.—The red Colour of the Blood derived from the Air in Respiration.—Dr. Priestley's Experiments.—Dr. Goodwin's Experiments.—The oxygenous Part of the Air diminished by Respiration.—Fixed Air generated in the Lungs in Respiration and expired.—Animal Heat produced by Respiration.—Instanced in different Animals.—Dr. Crawford's ingenious Theory.

UNINTERRUPTED respiration being necessary to our existence, it is wisely ordained, that this function should be so far involuntary as not to require a continual and irksome attention. For other purposes, as that of speech, respiration is no less wisely submitted in some measure to our direction, so that within certain limits we can accelerate or retard it at pleasure. We are sufficiently prevented, however, from suspending respiration to such an extent as to interfere with other processes absolutely necessary to the support of life, by being subjected, whenever we cease to breathe, to a sensation inexpressibly distressing, and which compels us to use every effort in our power to inhale air into the lungs.

The thorax, or that bony case which surrounds and protects the lungs, is furnished with a number of muscles, some of which, by drawing the ribs up-

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wards, enlarge its capacity, and others, by drawing them downwards, diminish it. Its capacity, however, is still more influenced by the muscular organ called the diaphragm, which from the breast bone and lower ribs passes obliquely downwards to the loins, and separates the thoracic from the abdominal viscera. By the contraction of the diaphragm, the abdominal viscera are pressed downwards and forwards, by which the lungs are permitted to expand themselves in the same direction; when the diaphragm is relaxed, and the abdominal muscles are thrown into action, a directly opposite motion takes place; the viscera of the abdomen are pressed upwards and backwards against the lungs, from which part of the air is consequently expelled.

The air, which is to be considered as possessing many properties in common with other fluids, possesses this, that by its weight it enters where it is least resisted. Part of the resistance to the entrance of the air into the lungs being taken off by the action of the muscles dilating the thorax, it rushes in through the windpipe, in the same manner as it rushes into the cavity of bellows, when the boards are separated from each other. Inspiration and expiration therefore are not performed by the lungs themselves, since air would be equally drawn into and expelled from the cavity of the thorax when deprived of lungs, supposing that the parts of the thorax could be made to perform their motions perfectly well after death. The lungs may therefore be compared to the cavity of bellows filled with any downy substance, the bones of the thorax to the boards of the bellows, and the muscles

cles of the thorax to the hands by which the bellows are moved.

Respiration may be divided into four stages or periods; first, inspiration; secondly, a pause when the lungs are filled; thirdly, expiration; and lastly, a pause when the lungs are emptied. We are equally stimulated to inspiration and expiration by a sensation of uneasiness, but that which is felt when the lungs are kept too long inflated after a full inspiration, is of a different kind from that which is perceived when they are preserved too long empty after expiration. In the former case the uneasiness is referred to the head, in the latter to the chest. To what these sensations are owing we cannot altogether determine; they are probably, however, to be attributed to the anterior cavities of the heart and the vessels of the head being overloaded with blood, which cannot so readily pass through the lungs while their motion is suspended. The truth of this opinion is much confirmed by the flushing of the face, and the bursting of blood vessels, which sometimes happens from impeded respiration.

The air, after passing through the windpipe, is conveyed by its ramifications to the air vessels of the lungs. After inspiration the air vessels, which are to be considered as very minute bladders with thin coats, are fully distended. The minute and very numerous ramifications of the pulmonary artery are distributed on the membranes of these air vessels; and through the membranes, without coming into direct contact with the blood, the air produces

produces those changes on it, which are found to be absolutely necessary for the continuance of life.

The chief uses of respiration, as far as our knowledge extends, are, 1st. To effect certain changes in the mass of blood; and, 2d. To produce animal heat. These effects, though no doubt intimately connected, I shall take the liberty of considering separately, for the sake of greater perspicuity.

The composition of the atmosphere has already been described, and it is at present only necessary to remind the reader, that rather less than three-fourths of the atmosphere is azotic gas, rather more than one fourth oxygen gas, and one or two parts in the hundred fixed air. The azote is not proved to have any effect in respiration, and seems to be merely a diluent of the oxygen gas, which is the principal agent. The fixed air contained in the atmosphere is probably also completely inert with respect to respiration. Previous to a more particular consideration of the nature of this function, it may not, however, be improper to throw together a few miscellaneous observations on that subject.

Animals breathing air contaminated by respiration, not only suffer for want of the pure part of that air, which is destroyed, but also from the fixed air which is produced. Mr. Cavendish asserts, that in certain diseases, and by certain persons, the air is much sooner rendered unrespirable. According to the observations of Dr. Priestley, insects appeared to breathe fixed air, or air otherwise contaminated, as readily as pure air. Flies, however, and other winged insects, have the property of
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destroying the salubrity of air by their own respiration, as may be observed by confining a few of those animals in a phial. These animals, indeed, appear less of the amphibious kind, and much more delicate, than when in the vermiform or maggot state.

Insects, and some exsanguious animals, will exist a considerable time without any thing equivalent to respiration. The same has been proved to be the case with fishes, though it is impossible to define the limits of their existence.

A vessel in which, when filled with common air, a mouse could not live more than half an hour, was filled by Dr. Priestley with vital air; a mouse then lived in it for three hours, and being taken out alive, the air was still found better, by the nitrous test, than common air.

From some experiments made by Dr. Goodwyn, he concludes that the lungs contain 109 cubic inches of air after a complete expiration; and that this quantity receives an addition of fourteen cubic inches by inspiration. The dilatation of the lungs, therefore, after expiration is to their dilatation after inspiration as 109 to 123.

One inspiration is commonly performed for every four or five pulsations of the heart, which latter, in different healthy persons, vary from sixty to ninety in a minute.

The blood undergoes remarkable changes of colour when circulating in the vessels of an animal; in the lungs it acquires a florid hue, which is gradually lost, while the blood is passing through the other parts of the body, again to be restored in the lungs. That the red colour of blood is owing to

the influence of vital air is manifest from actual experiment. Dr. Priestley introduced different portions of sheep's blood into different kinds of air, and found always that the blackest parts assumed a bright red colour in common air, and more especially in vital air; whereas the brightest red blood became presently black in any air unfit for respiration, as fixed air, inflammable, azotic, and nitrous gas, and after becoming black in the last of these kinds of air, it regained its red colour on being exposed to common or vital air, the same portions becoming alternately black and red.

It is proper, however, to mention, that Dr. Goodwyn introduced four ounces of florid blood, fresh drawn, into a glass receiver, containing fixed air, and confined it there for a considerable time; and also received blood from the carotid artery of a sheep into a phial filled with fixed air, but in neither of the experiments was the florid colour altered. These experiments do not accord with those of Dr. Priestley, but the following is intirely consonant with them. Dr. Goodwyn inclosed a quantity of vital air in a glass receiver inverted in quicksilver, and introduced into it four ounces of blood, fresh drawn from the jugular vein of a sheep; the blood became instantly very florid, and after several minutes the quicksilver ascended two or three lines, which evidently proved, that while the blood was altered in colour, the air was at the same time diminished in quantity.

It is well known that blood, when it coagulates on being exposed to common air, assumes on the surface

surface a bright red colour, while the inside is much darker, bordering upon black.

An objection, however, seems to arise to this hypothesis, viz. that though the blood in the lungs is not more than a thousandth part of an inch from the air, yet it never comes into actual contact with it. In order to examine the soundness of this objection, Dr. Priestley took a large quantity of black blood, and put it into a bladder moistened with a little serum, and tying it very close, hung it in a free exposure to the air, though in a quiescent state, and next day found, upon examination, that all the lower surface of the blood, which had been separated from common air only by the intervention of the bladder, had acquired a coating of a florid red colour, and as thick apparently as it would have acquired if immediately exposed to the open air.—In this case it is evident, that the change of colour could not have been owing to evaporation, as some have imagined. A piece of the crassamentum, surrounded by serum, acquired (not only on that part of the surface which was exposed to the air, but in those parts which were covered several inches with serum) a florid red, so that the deep covering of serum, which must have prevented all evaporation, was no more an impediment to the action of the air than the bladder. That it is really the air, acting through the serum, and not the serum itself, which gives the florid colour, is clearly ascertained by the following experiment: two equal portions of black blood were put into two cups, containing equal quantities of serum, which covered the blood in both to the depth of half an inch. One of the

cups being left in the open air, and the other being placed under the exhausted receiver of an air pump, the former presently acquired a florid colour, while the other continued twelve hours as black as at first. In another experiment, the reverse of the former, the influence of the air upon the blood was no less decisively proved; for red blood became black through the depth of two inches of serum, when the vessel containing it was exposed to azotic gas. Putrefaction, however, will produce a similar effect; for a small quantity of perfectly florid blood being put into a glass tube sealed hermetically, and thus cut off from all communication with external substances, became black in a few days. Except serum, milk is the only animal fluid, through which the air can act upon blood. By some subsequent experiments made by Dr. Priestley, he found that the intervention of a bladder by no means prevents the action of some airs on each other, as the nitrous on common air, &c.

The same industrious philosopher found also, that the air and blood employed in the above experiments undergo opposite changes; for vital air was vitiated by exposure to venous blood, and, on the contrary, inflammable air was absorbed, and foul air improved, by exposure to arterial blood. It has also been proved, that inflammable air will produce a change of colour in the blood, when introduced into the veins of a living animal.

The most remarkable change produced on air, which has been subservient to respiration, is the disappearance

disappearance of the vital air, and the production of fixed air. On account of the production of fixed air, indeed, an animal can only breathe a given quantity of air for a certain time, after which it sickens and dies. If a jar filled with vital air is placed over mercury, and an animal confined in it, after a time it will be observed to breathe with difficulty, and become very uneasy; if the animal is then taken out, and caustic alkali is introduced, a great diminution in the bulk of the air will take place; by the repeated introduction of the animal and the caustic alkali almost the whole of the air may be made to disappear, which proves that the vital air is by respiration converted into fixed air.

When we consider the composition of fixed air, which consists of the carbonaceous principle united with oxygen, we must conclude that the oxygen gas is converted into fixed air by the addition of that principle, which, in a state of extreme division, seems to be extricated from the lungs. By some physiologists, the extrication of this noxious principle has been considered as the only end answered by respiration. That this is not all, however, is proved by the consideration, that though part of the oxygenous gas is converted into fixed air by the addition of the carbonaceous principle, yet the weight of the air expired does not exceed that which is inspired. This naturally suggested the opinion, that a part of the inspired air was absorbed, nearly corresponding in weight with the matter discharged by the lungs. Dr. Priestley, by a series of experiments recorded in vol. lxxx. p. 106. of the Philosophical Transactions, has accordingly

proved, that a considerable quantity of vital air is absorbed by the blood. A very small portion of water is also thrown from the lungs at every expiration, which may be either an aqueous exhalation from the lungs, or may be formed by an union of vital air with inflammable gas.

The production of animal heat next properly claims our attention. That respiration is really the cause of animal heat can scarcely be doubted; for those animals which are furnished with lungs, and which continually inspire the fresh air in great quantities, have the power of keeping themselves at a temperature considerably higher than the surrounding atmosphere; but such animals as are not furnished with respiratory organs, are very nearly of the same temperature with the medium in which they live. Among the hot animals, those are the warmest which have the largest respiratory organs in proportion to the bulk of their bodies. This is particularly the case with birds, which have the greatest degree of animal heat. In the same animal, the degree of heat is in some measure proportionable to the quantity of air respired in a given time. Thus we find, that animal heat is increased by exercise and whatever accelerates respiration. By the word heat I do not mean a sensation, but caloric, or a peculiar fluid, having attractions for other substances, with which it is capable of forming combinations, and producing many important phenomena. We must carefully avoid estimating the quantity of heat contained in a body by its temperature, as indicated by the senses, or even by a thermometer; for water, wax, metallic bodies, &c. in passing from a fluid

to a solid state, lose a vast quantity of heat without any diminution of temperature; and it is well known, that a quantity of wax, &c. partly solid and partly fluid, is always of the same temperature, whether it tends towards the solid or the fluid state; that is, whatever is the temperature of the surrounding medium. If the wax is in a melting state, it absorbs the superfluous heat, which becomes latent; if on the other hand it is congealing, its latent heat is continually extricated, and sustains its temperature at a fixed point. Heat may therefore exist in a latent state, in which it cannot affect the thermometer.

There is still another difference with respect to the quantity of heat contained in bodies, independent of any change of form, similar to that which takes place in the combination of heat with ice constituting water. This latter difference is called a difference of capacity for heat, by which is understood an inequality in the quantity of absolute heat in two bodies, though their temperatures and weights are equal. Thus, if a pound of water and a pound of diaphoretic antimony have a common temperature, the quantity of absolute heat contained in the former is nearly four times that contained in the latter.

The following is a brief statement of Dr. Crawford's ingenious theory of animal heat. He made a series of experiments, by which he found, that the fixed air and aqueous vapour, which are discharged from the lungs, contain only about one-third part of the absolute heat contained in the atmospherical air, previous to its being respired: air, therefore, in being subservient to respiration, loses *part* of its

heat. He has also shewn, that the absolute heat of florid arterial blood is to that of venous nearly as eleven and an half to ten; since, therefore, the blood, which is returned by the pulmonary veins to the heart, has its quantity of absolute heat increased, he fairly concludes that it must have acquired this additional heat in the lungs. From the preceding observations it appears, that the production of animal heat depends on a process analogous to chemical elective attraction, and which is regulated by the following principles. Vital air contains more absolute heat, in proportion to its temperature and weight, than fixed air. The blood is returned to the lungs impregnated with the carbonaceous principle; the blood has less attraction for that principle than vital air has; in the lungs, therefore, it quits the blood to unite with the vital air. By this combination the vital air is changed into fixed air, and deposits part of its heat; the capacity of blood for heat is at the same time increased; the blood therefore receives that portion of heat which was detached from the air.

The arterial blood, in its passage through the capillary vessels, is again impregnated with the carbonaceous principle, and the basis of inflammable air, by which its capacity for heat declines; it, therefore, in the course of the circulation, gradually gives out the heat which it had received in the lungs, and diffuses it over the whole body. Thus it appears, that in its circulation through the lungs the blood is continually discharging carbonaceous matter and absorbing heat, and that in its passage through the other parts of the body it is perpetually im-

imbibing carbon and emitting heat. In this account of animal heat I have entirely omitted the absorption of vital air. This absorption was not admitted by Dr. Crawford, and, though established by the experiments of Dr. Priestley, does not at all invalidate the theory of the former philosopher. It is consistent with either hypothesis, that the blood in the lungs gains the heat which is lost by the air; and upon the truth of this proposition rests the theory of Dr. Crawford.

By the different capacity which blood possesses for heat in its different states, it is capable of supplying the different parts of the body with heat, while its own temperature remains the same. If this difference of capacity for heat did not exist, the extremities of the body could not be properly supplied with heat from the lungs, unless the lungs themselves were exposed to a degree of heat which would be certainly prejudicial, and, perhaps, such as no organised substance could support without destruction.

Dr. Crawford has moreover proved, by a course of experiments, that when an animal is placed in a cold medium, the venous blood acquires a deeper hue; that a greater quantity of air is vitiated in a given time, and, consequently, that more heat is absorbed by the blood. It appears, therefore, that nature has in this, as in many other instances, connected the occasion with the means of supplying it. Since, therefore, it is proved, that heat is absorbed from the air in respiration, and since the quantity absorbed is not only adequate to the purpose, but proportioned to the occasion, we may consider

sider ourselves as greatly indebted to Dr. Crawford for having thrown great light on a most important function, but which must still be enumerated, on some accounts, among those obscure processes of nature, on which human ingenuity may exert its powers, but which it can probably never completely reveal.

CHAP. XXXIII.

THE VOICE.

Instrument of Sound in the Animal Body.—The Larynx.—Experiments on the Windpipes of different Animals.—Whether the Larynx acts as a wind or stringed Instrument.—Singing, how performed.—Speaking.—Whispering.

ALL animals, as far as our observations extend, have the power of communicating their sensations or ideas to each other, and the principal means of this communication is the voice. Man is indebted to this function for the satisfaction of social intercourse, and in a great measure also for his distinguished pre-eminence above other animals in mental acquirements.

The instrument of the voice is the larynx, and the immediate occasion of it is, the expulsion of the air from the lungs through this organ exciting a vibratory motion in the whole larynx, but more particularly in the ligaments which pass from the scutiform to the arytenoid cartilages. That the larynx is really the instrument of the voice has been fully proved by an ingenious anatomist* of our times, who, after detaching the windpipe from the bodies of different animals, by relaxing or shortening the tendinous bands at the extremity of the windpipe, and blowing in at the opposite end, found

* Ferrein.

means to produce all the different cries and tones of which the living animals were capable. On the different structure of the larynx depends the different voices of animals; thus birds, which have a shrill and piercing note, are found to be possessed of a narrow larynx; animals, which are hoarse or mute, of a wide one. The same fact is proved in ourselves. We may perceive, by applying the finger to the throat, when we endeavour to produce a shrill tone, that the larynx is contracted, rendered tense, and elevated; when we produce a grave sound, it is enlarged, relaxed, and depressed; by endeavouring to produce a graver tone than we are capable of, the larynx is too much relaxed to perform its office, and the air passes through it without producing any sound whatever.

Bonnet observes, that birds are furnished with what may be called two larynxes, the one at the superior extremity of the windpipe, as in men and quadrupeds; the other (which is the principal organ of sound with them) at the inferior extremity, and close to the bronchiæ. The chief instrument for the modulation of the voice in this lower larynx is a membrane situated transversely between the two bronchiæ, communicating with other membranes, resembling the reed of a hautboy. On the greater or less elasticity of these membranes depends the tone of the voice, in the same manner as in other animals it depends on the tension or relaxation of the cords of the glottis*.

It has been much debated, whether the larynx, in producing the voice, acts as a wind or a stringed

* Bon. Cont. p. 7.

instrument;

instrument ; but there can be little doubt, from the structure and motions of the larynx, that it possesses the advantages of both.

Singing is a modulation of the voice, through various degrees of acuteness and gravity, and is performed almost solely by the larynx, though the nose and mouth are in some degree concerned in improving and softening the tones. During speech, the larynx is pretty much at rest, as very little variety, with respect to gravity or acuteness of voice, is requisite. The voice being produced in the larynx, is afterwards formed into letters, syllables, and words, by various motions of the tongue and lips. The larynx is very little, if at all, employed in whispering, and seems to transmit the air in this case as a simple tube, like the windpipe.

CHAP. XXXIV.

MUSCULAR MOTION:

Inquiry whether any Thing equivalent to muscular Motion is to be found in the other Parts of Creation.—Different Hypotheses concerning the Cause of muscular Motion.—Its Dependence on the Will.—Contractile Power of Muscles after Death.—Extent of the Contraction of Muscles.—Advantage from the Obliquity of certain Muscles.—Insertion of the Tendons.—Force of Muscles.

THE power of contraction, with which the muscles of animals are endued, and by which they perform all the motions of the body, is different from any property inherent in any other kind of matter. But though the most remarkable examples of muscular contraction are observed among animals, yet we are by no means authorized to conclude, that the vegetable kingdom is wholly destitute of similar powers; on the contrary, the expansion and contraction of the flowers and leaves of plants, according to the degree of heat, and the circulation of their sap, are strong arguments in favour of the opinion that they are furnished with organs truly muscular; and the convulsive motions excited by touching the stamina of certain plants seem to place this matter beyond dispute.

Under the head of anatomy, the general outlines of the structure of the muscular organs have been

been already considered ; but nothing further was advanced on the present subject, than that muscles are contractile masses composed of numerous minute, and in general red *, fibres, combined together in bundles by cellular substance. Such, therefore, being the structure of muscles, little credit appears to be due to the supposition, that muscular contraction depends on an influx of blood or any other fluid into minute bladders or cells ; and it must remain undetermined, whether the ultimate moving fibres are tubular or solid ; whether they consist of chains of rhomboidal vessels, as has been imagined by some physiologists, or whether, as others have thought, they contain a kind of down or woolly substance.

When muscles are thrown into action, they become shorter, broader, and more dense, or solid, to the touch ; their bulk does not seem to be on the whole increased, nor are they found to be of a paler colour.

Muscles never act but from some exciting cause ; of these one of the most frequent and curious is volition, by which every day's experience teaches us we have the power of throwing the greater number of our muscles into action. Over some of our muscles, however, as those of the intestines, and the heart, the will has no influence, and these are therefore called muscles of involuntary motion. What is the nature of the influence which the will exerts over muscles, we can never hope to discover ; but it is of importance to remark, that the

* The colour proceeds from the blood, which they contain in minute vessels.

nerves are the organs by which this influence is exerted ; for the nerve leading to any particular limb being divided, we are no longer able to move that limb at our pleasure.

Besides, however, being influenced by the will, muscles are thrown into action by several other causes, such as chemical or mechanical injury, and still more remarkably by the electric shock, which influences muscles insensible to every other known stimulus.

Muscles retain a contractile power for a considerable time after they are removed from the living body ; this power, however, gradually diminishes, till, sooner or later, according to a variety of circumstances, it ceases altogether. The muscles of involuntary motion, when removed from the rest of the body, retain their contractile power longer than those of voluntary motion ; the former, indeed, from this circumstance, as well as from their uninterrupted motion in the living body, seem to be possessed of a capacity for contraction beyond that of the other muscles.

What has been hitherto stated, relates principally to the more remarkable muscular contractions, by which the actions of the body are performed ; but it is to be remembered, that besides these occasional contractions, there is a continual tendency in the muscular fibre to shorten itself ; and even after death, when a muscle is divided, the wounded extremities recede from each other. A strong illustration of this circumstance is obtained, by observing the consequence of dividing a muscle in the living body, for in this case its antagonist will constantly

stantly draw the part which these muscles were designed to move, towards its own side.

That power by which the different parts of a muscle, divided after death, recede from each other, is called the *vis mortua*, and is common to muscles and other animal fibres. The power by which a muscle obeys a stimulus after being separated from the body, or after its communication with the sensorium has been cut off by other means, as by dividing or tying its nerves, has been called its *vis insita*. This power is more peculiar to life; and though it may continue for a few hours after death, yet it disappears much sooner than the former. It was supposed by Haller to exist wholly independent of the nerves, but this opinion has neither been established nor refuted. The capacity of muscles to obey the influence of nerves, is called the *vis nervea*. The power which we possess of calling the muscles into action by a voluntary effort, depends on a relation established by God, and not on the directing influence of the human soul, since we have no conception of the intimate structure either of the nerves or muscles. It is true, that by habit we acquire a more exact command over our muscles in most instances, yet the operation of sucking, in which a variety of muscles operate in a complex manner, is performed by a new born infant; and the young of many animals can walk immediately after birth.

The extent of the contraction of a muscle has been limited by some anatomists to one third of its length. This statement, however, though it may be nearly just with respect to the greater number of muscles,

is by no means true with respect to all. The muscular coat of the bladder for example, will admit of that organ containing a quart of fluid matter, without much inconvenience, and at the same time is so contractile as to be capable of expelling almost every drop in a very short time.

But the extensive effect of muscular contraction is not owing only to the degree to which a muscle can shorten itself, but also to the direction of its fibres. Thus oblique muscles produce a much more extensive motion than those which are strait, and this extensiveness of motion is proportioned to the obliquity of the muscle. What is gained, however, in extensiveness of motion by the obliquity of fibres, is lost in force; but this is more than compensated by the oblique structure, allowing space for a much greater number of muscular fibres. Oblique muscles have therefore in both respects the advantage over those which are strait, and are accordingly much more numerous in the animal machine.

There is no part of the structure of the animal body, which is more calculated to excite our admiration, than the manner in which the tendons of muscles are inserted into the bones. If for instance, the muscle called the biceps, which lies at the inside of the os humeri, and which is designed to bend the fore-arm, instead of terminating at the upper part of the radius, had been inserted half way between the elbow and wrist, it is evident, that when the muscle had contracted itself so as to bring the fore-arm to a right angle with the os humeri, the tendon must have started several inches from its place, and have given the limb a very unpleasant appearance,

pearance, and must also have been attended with several real inconveniences. By the tendon, however, being inserted near the joint, the motion of the limb is performed without so great a rising of the tendon as to prove troublesome. By this structure moreover, the motions of the limb are much quicker than if the tendon had been inserted lower down towards the wrist. By the tendon being inserted nearer the axis of motion, it is also evident, that a much smaller contraction of the muscle is sufficient to produce an effect, than must have been necessary to produce the same had the insertion of the tendon been half way between the elbow and the wrist. That universal rule in mechanics, however, that what is gained in quickness is lost in force, it must be remarked, is applicable to this case, so that some loss of strength necessarily attends the acquisition of superior celerity. But this inconvenience has been obviated by a very simple expedient, that of making the muscle stronger than would otherwise have been necessary.

Many very erroneous calculations have been made with respect to the force of muscles. Borelli has been led to conclude that the heart at every contraction exerts a force equal to 100,000lb. while others have pretended to discover that this force does not amount to many ounces. With respect to the heart, however, we really have not data on which we can proceed with any tolerable degree of precision. There is no muscle in the body more conveniently situated for having the force of its contraction determined than the biceps of the arm. It will be foreign from our present

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purpose

purpose to mention all the steps of the calculation with the gross result of which I shall in this place present the reader; it is indeed merely mentioned as probable, that when we raise forty pounds weight by means of the fore arm, the biceps exerts a force at least equal to five or six hundred pounds.

The surprizing muscular force of the turkey's gizzard, has been already noticed.

From these observations, it appears, notwithstanding the great visible exertions of muscular force, that the greater part of their real power produces no apparent effect. For all muscles are inserted nearer the center of motion than the weights on which they act, and their effect is therefore less in proportion to the shortness of the lever on which they act. In most of the limbs the muscles are inserted at very acute angles, which throws their force more nearly in the direction of the center of motion, and consequently lessens their effect. Many muscles pass over projecting bones, which increases friction. But besides all these causes diminishing the power of muscles, one half of their strength is exerted on their fixed extremity, for a muscle in action, like an extended cord, exerts an equal force at both extremities.

CHAP. XXXV.

ANIMAL ELECTRICITY.

Accidental Discovery of M. Galvani.—Animal Electricity only excited by Metals.—Experiments on dead Animals.—Conductors and Non-conductors of this Power—Experiments on the living Subject.—On Earth Worms, &c.—Analogy between this Power and Electricity.—Shock of the Torpedo.—Nervous Energy.

AMONG the late discoveries in philosophy there is not any more curious than that relation which is found to exist between certain metals and the nervous and muscular system of animals, which has received the name of animal electricity. How far it is consistent with truth to refer this influence to the laws of electricity may be a proper subject of inquiry, and perhaps of skepticism; but it will be necessary previously to relate the principal facts which have been ascertained on a subject so novel in physiology, and so little analogous to the known principles of animal existence.

The shock which the muscles of the human frame receive from the touch of the torpedo, and of the electrical eel, had long been known; but that the animal fibre when deprived of the principle of vitality should be subject to a similar influence, was a discovery reserved for the present age. M. Galvani, the professor of anatomy at Bologna, observ-

ing one day certain involuntary contractions and motions in some frogs, which, with little credit to the professor's humanity, had been hooked by the back-bone and suspended from the iron palisadoes of his garden, his curiosity was powerfully excited, and on examining minutely into the cause of these contractions, he found that he could produce them at pleasure, by touching the animals with two different metals at the same time in contact with each other.

From later observations it seems to be sufficiently ascertained that these involuntary contractions cannot be excited by any substances whatever, whether solid or fluid, except the metals, and that the mutual contact of two metals with each other is, in every case, necessary to the effect. Zinc has been found by far the most efficacious, especially when in contact with gold, silver, molybdena, steel or copper, although these latter excite feeble contractions when in contact only with each other. Next to zinc, tin and lead seem to be the best exciters. When the pieces of metals employed, and the surface of the animal fibre with which they are in contact, are large, the contractions excited are in general more considerable, but by no means in proportion to these circumstances.

In order to observe the phenomena in question, cut off the head of a frog. When it has ceased to struggle, apply a plate of zinc under its body, and a plate of gold to the superior surface. Then slide the gold plate till it comes in contact with the zinc, when the muscles which are further from the brain and

and spinal marrow than the metals, will be thrown into contraction.

This effect will take place, although the frog with the metals are placed on an inverted glass jar, and a stick of sealing-wax is interposed between the hand of the operator and the metals, that is, although the animal as well as the metals is insulated. I mentioned gold as being the most powerful of the metals, but a plate of silver, a crown-piece for instance, will answer the purpose.

Cut off the thigh of a frog just killed close to the body, and lay bare the sciatic nerve. Place the nerve in contact with a piece of zinc, and let its foot rest on a piece of silver; on bringing the two metals into contact, the muscles of the limb will be convulsed.

If a piece of brass wire is made to touch at the same time the metals disposed as above described, a communication will be formed between them, and the contraction of the muscles will equally take place.

If the nerve is made to rest on a piece of zinc, and the zinc is touched with a plate of silver held in one hand of the operator, while with the other he takes hold of the foot of the frog, the influence will pass through the body of the operator, and the limb will also be convulsed.—These experiments must be performed before the nerve becomes dry by exposure to the air.

In order that these contractions should be produced, it is not necessary that either of the metals should be in actual contact with the animal in which the convulsions are to be excited; as

the interposition of pieces of boiled or putrid beef were found by Dr. Monro not to prevent the effect.

By an experiment of Dr. Fowler the same fact is proved. He found that if a frog, of which the head should be first cut off, is divided into two parts, just above the origin of the sciatic nerves, and put into a basin of water, the hind legs may be thrown into strong contractions, by bringing zinc and silver into contact with each other, at the distance of at least an inch from the divided spine, so long as they are kept nearly in a line with it. Water in this case is the only communication between the metals and the origin of the nerves.

Dr. Fowler remarks, that he has frequently passed this influence through a great length of thin brass wire, and through the bodies of five persons communicating with each other by dipping their fingers in basins of water placed between them; yet it did not appear to have lost any of its force in this long and diffused passage; for the contractions excited in the frog's leg were equally strong, as when it had passed only through one person. Dr. Fowler made many experiments in order to discover what substances were conductors and what non-conductors of this influence. He found that all metals when pure were excellent conductors; that they were not quite so good when in the ore; and as far as he could ascertain, least so when in the state of metallic salts. From trials which he made with some of the calces of metals he concludes, that in that state their capacity as conductors is quite destroyed. Stones seemed to be possessed of no conducting power.

The different non-conductors of electricity were found to be non-conductors of this influence. Living vegetables afforded it a ready passage, probably from the fluids which they contain. Oils of all kinds were so far from conducting, that if the fingers of the person holding either the probe or the zinc have perspired much, even this operates as a complete obstruction to the passage of the influence; the instant the perspired matter has been wiped away, and the fingers have been dipped in water, it again passes and excites contractions. Dr. Fowler wished to ascertain whether it passed over the surface or through the substance of metals; he coated several rods of different metals with sealing-wax, leaving nothing but their ends, by which they were held, uncovered. Contractions were excited as readily through the medium of these, as if they had not been coated. It seems to meet with no obstruction in passing from link to link of several chains, even when no pressure, except that of their own weight, is used to bring them into contact. Dr. Fowler was led from this to hope, that he should be able to make it pass through a very thin plate of air. He therefore coated a stick of sealing-wax with a plate of tin-foil, and then made an almost imperceptible division across it with a sharp pen-knife; but even this interruption of continuity in the conductor was sufficient effectually to prevent its passage.

Dr. Fowler next proceeds to examine whether the capacity of different substances, as conductors or non-conductors, was at all effected by differences of their temperature; but this was not the case

case with zinc, iron, water, coal, or a common crucible, the only substances with which he tried the experiment.

The effects of this influence may be felt in ourselves by a very easy experiment. If a piece of lead is applied to the upper part of the point of the tongue while a piece of silver is applied to the under part, upon bringing the two metals into contact, a somewhat pungent sensation will be felt, accompanied by a strong metalline taste of some duration. The same sensation takes place though both of the metals are prevented from touching the tongue by the interposition of moistened paper.

Dr. Fowler says, he could never perceive that the senses either of touch or smell were in the least affected by the metals; but the effect which they produce on the eye is very remarkable. Having laid a piece of tin-foil on the point of his tongue, he placed the rounded end of a silver pencil case against the ball of his eye, in the inner canthus, and suffered them to remain in these situations till the parts were so accustomed to them, that he could examine the sensations produced; he then brought the metals into contact with each other, and to his surprise, perceived a pale flash of light diffuse itself over the whole of his eye. His tongue was at the same time affected with a similar sensation to that produced when both of the metals are in contact with it. On darkening the room the flash became more distinct and of a stronger colour. If the experiment is made with zinc and gold, instead of tin-foil and silver, the flash is incomparably more vivid. By insinuating a rod of silver as far as possible

possible up the nose and then bringing it into contact with a piece of zinc placed upon his tongue, he also succeeded in producing the sensation of a flash of light, rather more vivid than when the silver was in contact with the ball of the eye. Dr. Fowler also mentions that his friend, Mr. George Hunter of York, discovered that by placing one of the metals as high up as possible between the gums and the upper lip, and the other in a similar situation with regard to the under lip, a flash was produced as vivid as that occasioned by passing one of the metals up the nose, and placing the other upon the tongue. It differs, however, from the flash produced in the other way, in the singular circumstance of not being confined to the eye alone, but appearing diffused over the whole face. On repeating the experiment myself, and attending to the concomitant sensations produced by this disposition of the metals, I perceived that a sense of warmth, at the instant that they were brought into contact, diffused itself over the whole upper surface of the tongue, proceeding from its root to the point. Dr. Rutherford, to whom Mr. Hunter had communicated this experiment, remarked, on repeating it, that a flash is produced not only at the instant the metals are brought into contact, but likewise at the instant of their separation; while they remain in contact no flash is observed. These curious phenomena demonstrate the free communication which subsists between the several branches of the fifth pair of nerves.

The following curious fact is also taken from Dr. Fowler's ingenious and entertaining book on animal electricity.

electricity. He laid a leech on a crown-piece of silver, placed in the middle of a large plate of zinc. The animal moved its mouth over the surface of the silver without expressing the least uneasiness; but having stretched beyond it and touched the zinc plate with its mouth, it instantly recoiled as if in the most acute pain, and continued thus alternately touching and recoiling from the zinc, till it had the appearance of being extremely fatigued. When placed wholly upon the zinc, it seemed perfectly at its ease; but when at any time its mouth came in contact with the silver lying upon the zinc, the same expression of pain was exhibited as before. With the earth worm he found that the experiment succeeded still more decisively. The animal sprang from the zinc in writhing convulsions; if, when the worm stretched itself forwards, one of the folds came upon the zinc, it expressed little uneasiness in comparison of what it shewed when the point of its head touched the zinc.

Whether this influence, whatever it may be, is derived from the metals alone, or whether the animals contribute to its production, is not easy to determine.

On re-considering the phenomena exhibited by this newly discovered influence, we shall perceive that in some respects it remarkably resembles electricity, and in others as remarkably differs from it.

Like the electric fluid, it stimulates muscles to contraction. Like that, its progress is arrested by glass, sealing wax, &c. while it is conducted by metals, moisture, &c. Dr. Valli informs us, that he observed the hairs of a mouse, attached to

to the nerves of frogs by the tinfoil with which he surrounded them, alternately attracted and repelled by each other, whenever another metal was so applied as to excite contractions in the frogs.

Like the electric fluid, it excites a sensation of pungency in the tongue; and passes with similar rapidity through the bodies of animals.

It differs from the electric fluid in many respects.

In order to excite the electric power, it is necessary that there should be motion or friction between two substances, an electric and a conductor. Animal electricity is produced by two metals, which are both conductors and without friction.

According to Dr. Fowler, charcoal is a better conductor of electricity than the fluids of animal bodies. Whereas he never could make the influence in question pass through charcoal.

Dr. Fowler in opposition to Dr. Valli alledges, that he could not observe that the nicest electrometers were affected by this influence.

The same author remarks, that the most important and characteristical difference which he has yet been able to discover between this new influence and electricity, consists in their effects upon the contractile power of animals and of plants. The contractions of animals excited by electricity, have a tendency to destroy that power upon which contractions depend. But the contractions excited by the application of the metals, have in all his experiments

experiments had the directly opposite effect. The more frequently contractions have been in this way excited, the longer they continue excitable; and the longer are the parts upon which such experiments are made, preserved from putridity.

It is said that a stream of electricity passed through a sensitive plant, produces an almost immediate collapse of its leaves; but the influence in question produced no such effect in an experiment made by Dr. Fowler.

The same attentive experimentalist electrified both positively and negatively frogs, whose heads had been separated from their bodies. In these circumstances the effects of the influence in question took place in the same manner and degree as when no artificial electricity was present.

When there is a breach of equilibrium in the distribution of the electric fluid, all that is required in order to restore the equality of distribution, is the interposition of a single conducting substance between the place in which it abounds, and that in which there is a deficiency; whereas if the phenomena of animal electricity are to be attributed to the same cause, it does not appear why *two* conducting substances should be necessary.

In establishing a communication between two opposite electricities, as for example, between the two sides of a charged phial, it is matter of indifference to which the conductor is first applied; but it is by means so, in producing the phenomena of animal electricity; for if one branch of a conductor is applied to the tin-foil arming a nerve, before the
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the other branch has been applied to the muscles, it frequently fails to excite contractions. If first applied to the muscles, this is very seldom the case.

From some trials which Dr. Fowler made with the artificial and natural loadstones, and a very sensible magnetic needle, he saw no reason to suppose that this new influence was in any way connected with magnetism.

Animal electricity is even found to differ, in some respects, from that power by which the torpedo, gymnotus, &c. produce their shocks. We are told by Mr. Cavendish, that Mr. Walsh found that the shock of the torpedo would not pass through a small brass chain. It resembles the power of the torpedo, however, in producing its effects almost equally well, when both it and the subject upon which it acts are insulated from surrounding conductors. The shock of the torpedo, &c. seems to depend entirely on the will of the animal; but the will of the animal has no share in the production of the phenomena discovered by Galvani.

That this influence is not the same with the nervous energy appears from its not being stopped by a tight ligature, or by the transverse incision of a nerve, provided its parts are again brought into close contact. The nervous energy is effectually stopped by a tight ligature or a transverse incision; and placing the divided extremities into the closest contact has no effect in restoring its influence on the parts of the body to which the divided nerve was distributed.

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On the whole it may be remarked, that the influence discovered by Galvani resembles electricity more than any other known law of nature. But it differs in so many instances even from it, that in the present state of our knowledge, we must consider it as a newly discovered law in nature; though future experience and more extensive observation may lead to a different conclusion.

CHAP. XXXVI.

SENSATION.

Difficulty of the Subject.—Sensation the Effect of certain Relations established by the Creator.—Objects of different Senses.—Influence of the Nerves in conveying Sensations to the Brain.—The Brain the Repository of Ideas.—Instinct of Animals as connected with the nervous System.—Harmony of the Senses.—Duration of sensible Impressions.—The Five Senses.

FROM the consideration of the other functions to that of sensation, the transition must be abrupt and without gradation. We now enter on a subject above all others the most intricate and difficult, and on which, since reason is engaged in discovering the source whence it derives those ideas on which it acts, we must necessarily reason in a circle.

Sensation is the link, by which the Deity has connected the material to the immaterial world. Without sensation, in vain would the stars have bespangled the firmament of heaven, in vain would that glorious object the sun have been appointed to illuminate and cherish the productions of the earth; they could have been nothing to beings who must have been unconscious even of existence; and the material world would have been a work without utility or design.

Sensation is the consequence of certain established relations between objects; of these relations we

can give no account, for they appear equally above our comprehension with the principles of gravitation, electricity, or magnetism. Relations between the matter of light, the objects of vision, and the eye, produce sight; relations between certain vibrations of the air and the sensorium of the ear produce hearing, and so of the other senses. We by no means, however, can pretend, in any of these cases, to determine all the intermediate causes and effects between the quality in a body, which renders it an object of sensation, and the perception in ourselves; nor are we by any means authorized to conclude, that our perceptions are just emblems of the objects which occasion them. But this circumstance, upon which so much has been said, can be to us of little importance, since it still remains equally true, that our sensations are regulated by fixed laws established by the Deity himself, and since we must suppose that the Creator of the universe has ordered all things in wisdom and goodness.

We are ignorant of the means by which the objects of sensation affect the body; but the most obvious and simple idea that we can form on this subject is, that they act by impulse. Thus the rays of light are known to travel with astonishing velocity, and to possess a power of moving light bodies. Sound is a tremulous motion of the air, capable of being communicated to bodies in harmonic proportion with it. Odorous particles require the assistance and motion of air to affect the organs of scent. The objects of taste are more perfectly perceived by being pressed between the tongue and palate. In order to feel any thing, it is necessary
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that the skin should be pressed against it with a certain degree of force, or, what is still more effectual, rubbed over its surface.

The instruments, which are designed to convey the effects produced by material objects on the organs of sensation to the brain, are the nerves, which have been already described as distributed to the several parts of the body, and more particularly to the organs of sensation. What is the difference of structure, which adapts the several nerves to the several organs of sensation, we know not, nor can we determine whether certain parts of the brain correspond with the nerves connected with certain organs of sensation, and are destined to preserve the ideas received by these particular organs, or whether the whole brain is common to the whole stock of our ideas and sensations; though these have been subjects of much speculation, it has not even yet been ascertained, whether any material impression whatever takes place in the brain in consequence of impressions on our senses; and until this question is determined, we cannot be prepared to examine the other. That the brain, however, is really in some way or other the repository of our ideas, we may venture to conclude, since a person who loses an organ of sensation does not lose the ideas previously acquired by it; and since persons sometimes complain of pain, seated in the extremity of a limb of which they have long since been deprived.

There have been of late years some curious speculations among philosophers with respect to the material cause of instinct in animals, and as there

is some plausibility in their reasonings, it may be worth while briefly to mention the outlines of their system. They suppose that the motions of animals, commonly called instinctive, arise from a connection of the nerves belonging to different parts in the brain. In this manner, when the young bird hears the call of its mother, and opens its beak, they suppose this effect to be owing to an original connection between the auditory nerve and the nerves communicating with the muscles employed in opening the bird's beak. When a new-born quadruped performs the complex action of sucking, in consequence of the application of its nose to the teat of its mother, they attribute its capacity for executing a function, in which so many muscles are employed, to a connection originally existing in the brain, between the nerves of its nose and those which belong to the organs employed in sucking. The most complex instinctive actions of animals, according to these philosophers, may be explained on the same hypothesis.

The qualities of bodies, as perceived by one sense, are very frequently connected with others perceived in the same bodies by the other senses: thus, apparent unevenness of surface, is united with a roughness to the touch; apparent vibration, with sound; and there is a certain analogy between the odours and tastes of many bodies. These conclusions, however, are to be referred to our previous experience, and by no means authorize us to think that there is any similitude in the mode of perception between the senses of seeing and hearing, seeing and feeling, or tasting and smelling. It is said, that there have been persons who could distinguish

guish colours by the sense of feeling ; but if they did, it must evidently have been from some difference of roughness, smoothness, &c. resulting from the materials employed in colouring, and not from any property inherent in the different colours as objects of sight.

It is ordained by our Creator, for the most important purposes, that our sensations should not be too evanescent ; and it requires some time after one impression is made on an organ of sense, before that organ can receive another. This is proved by a very simple and decisive experiment. All of us have probably observed, when a stick lighted at one end, or a coal, is whirled round with a certain degree of velocity, that the whole circle which it performs appears equally illuminated, and that we cannot determine at what point of the circle the fire really is ; and the same circumstance may be observed in the blending of colours, which are yet marked distinctly on a wheel before it is turned. The evident cause of these appearances is in the eye ; and in the first case, when we fix our eye on any point of the circle made by the evolution of a lighted coal, the illuminated object again returns to that point before the sensation previously produced is worn off : and the blending of the colours on a wheel is explained in the same way ; for the impression made by one colour remains till the other arrives and mixes with it. It is also well known, that persons who have the best and quickest ears for music cannot judge accurately of more than a certain number of notes in a second of time. Innumerable facts, indeed, may serve to convince us,

that the mind cannot well attend to two or more sensations at the same time *. Hold your tongue, said a Frenchman, you talk so I cannot taste my meat. The Frenchman was certainly right; for attention of mind is not less necessary to full perception, than a healthy state of the organ of sense.

All authors are agreed, that our knowledge of external objects is entirely acquired through the medium of sensation, though some persons of the highest rank in literature and philosophy still contend, against Mr. Locke, in favour of the existence of certain innate and instinctive principles; but if I was disposed to enter into the dispute, this would not be the proper place.

The senses are five in number: touch, taste, smelling, hearing, and sight. Of these I shall endeavour briefly to treat in their order. I have in general considered it as more conducive to perspicuity to separate the anatomical description of the organs from the functions to which they are subservient; but as the organs of sensation are small, and at the same time not much connected with the great outlines in the structure of the body; and as the

* The contemptible vanity of Cæsar, in pretending to perform several mental operations at once, proceeded from a real ignorance of the human mind. The reply of the justly celebrated pensionary De Witt was much more judicious, and ought to be impressed on the mind of all young persons. On being asked how he contrived to transact such a multiplicity of business in the course of a day without neglect or disorder, he answered, "I make it a rule always to attend to one object at a time."

organs of some of the senses, particularly that of hearing, are complex, and very difficult to be retained in the mind, I have, in this instance, thought it necessary to depart from the former arrangement.

C H A P. XXXVII.

TOUCH, AND ITS ORGANS.

The most extensive of the Senses.—Organs of Touch.—In what Manner it enables us to judge of the Qualities of Bodies.—Young Man couched by Cheselden.—Remarks on his Case.

IN order to protect the body from injury, almost every part of it is so formed as to give warning to the mind when any thing injurious assails it. The whole body may therefore, in the most extensive sense of the word, be deemed an organ of touch. The internal parts of the body, however, though they are capable of feeling, yet convey no other idea but that of pain, and give us no information with respect to the nature of what is applied to them. The whole surface of the body is endued with a much more extensive power, and informs us of several qualities of matter; but the lips, the tongue, and, above all, the fingers, afford us the most accurate information of those qualities of bodies which are the objects of this sense.

When the epidermis is removed from the true skin, we observe small obtuse papillæ, which seem to be the parts which more particularly receive the impressions of external objects. These papillæ are somewhat more remarkable in the skin at the ends of the fingers, and here we may perceive, that they have nerves, though from the extreme minuteness of them they are hardly observable. We judge

of

of heat and cold from the object being hotter or colder than our fingers *; of the weight of a body, from its degree of pressure compared with its bulk; of its moisture, by its coldness, or the presence of water; of its softness, by its yielding; of its hardness, by the yielding of the finger; of its figure, by applying our hands to its different parts; of distance, by comparison with what we know to be the length of the finger, hand, or arm. All our conclusions, however, are so regulated by previous experience, and we so seldom trust to the evidence of touch without also calling in the assistance of vision, that without the latter sense the conclusions drawn from the other would be very limited and imperfect. Touch is the sense by which we acquire a knowledge of the distance of objects, which, independent of experience, obtained by means of this sense, is not to be discovered by vision. This circumstance was beautifully illustrated in the case of a young man, as stated in Cheselden's anatomy. This young man, born blind, and being suddenly enabled to see, in consequence of a surgical operation, imagined that every thing he saw touched his eyes, and it was only by repeated trials of the distance of objects, by means of touch, that he was taught to correct his error.

From this fact, however, it is not perfectly evident, that an infant, born with all its senses perfect, would naturally conclude that the objects of vision touched its eyes. Might not the young man, from

* The tongue is a more nice test of the warmth of a body than the fingers, for we can feel a warmth at the larger end of an egg with the tongue, which is not perceptible by the fingers,
being

being so accustomed to judge of objects by their feel, or by applying them to his tongue or nose, have acquired the idea, that nothing could be perceived which was not in contact with the body? and thus the conclusion which he drew might really depend on the association of ideas.

CHAP. XXXVIII.

TASTE, AND ITS ORGANS.

The Tongue the Organ of Taste.—Description of it.—How supplied with Nerves.—Muscles of the Tongue.—How Tasting is performed.

THE tongue has been already casually mentioned as in some respects a very accurate organ of touch; but the sense to which it is more particularly subservient is that of taste. The palate is commonly considered as the organ of taste; but this is a vulgar error, for unless the substance applied to the palate has some degree of acrimony, no sensation whatever is the consequence. The tongue, and more particularly at the point, and the superior and the lateral parts of it, is the true organ of taste. The skin, with which the tongue is covered, is remarkably soft and thin, and is continually preserved moist and warm. On the surface of this skin papillæ, much larger than in any other part of the body, and of several sorts, are observable. The first kind are few in number, and are placed at the back part of the tongue. These are surrounded with a small furrow, and their form is almost that of an inverted cone. They are not of a very delicate structure, nor are they much concerned in tasting. The second kind, which are smaller and softer than the preceding, and into which the first gradually degenerate, have somewhat

what of the form of a mushroom ; they are scattered on the superior surface of the tongue, till, becoming more numerous towards its sides, they are there distributed in diverging lines. The third kind are of a conical form, are mixed with the other kinds, and are very generally distributed over the whole superior part and sides of the tongue. They are endued with a very acute power of sensation, and are the true organs of taste. These conical papillæ differ greatly in their size ; and some of them are extremely minute. On an accurate examination we also find some filiform papillæ placed in the interstices of the conical.

These papillæ, besides being copiously supplied with blood, are also furnished with nerves, of which the tongue receives more, in proportion to its bulk, than perhaps any other part of the body. The exhaling arteries, which are numerous distributed on the surface of the tongue, have no further concern in the sense of tasting, than as they help to moisten and keep the papillæ in a fit state to perform their office. On the upper, and towards the back part of the tongue, are two or three openings, which pour out a mucous fluid. The papillæ in man are covered with a thin and semipellucid membrane, which answers the purpose of an epidermis. In many animals, as those which feed on grass, the tongue is covered with a very rough and thick membrane, perforated so as to admit the dissolved food to the papillæ, which are placed beneath it.

Under the papillæ is placed the muscular substance of the tongue. The muscles, which constitute this substance, are so numerous, and are so confounded

founded with each other and with the fat, that the most diligent anatomist is unable to trace the course of many of them. By the help of these muscles the tongue is moveable in all directions, and may be rendered broad, narrow, or hollow, at pleasure. The tongue is very plentifully supplied with blood-vessels.

A circumstance universally necessary to a body being tasted is, that it should be dissolved in the saliva, and in that state applied to the papillæ.

C H A P. XXXIX.

SMELLING, AND ITS ORGANS.

Final cause of this Sense.—Less acute in Man than in some other Animals.—Different also from theirs.—Description of the Organs of Scent.—Comparison between this Sense and that of Taste.

AS one principal use of the organs of smelling is to assist animals in obtaining proper food, and to guard them against what is improper, they are universally placed near the mouth. The organs of smell differ, like those of the other senses, according to the destination of the animals to which they belong. This sense in man is far less acute than that of many other animals; thus, the dog possesses a power of smelling, of which we can scarcely form a conception, and which we happily do not possess. Birds of prey, however, are said to have the sense of smelling still more acute than dogs. The sense of smelling in man is such as to fit him for deriving enjoyment from a diversity of scents, particularly those of flowers, to which dogs and other animals, which do not feed on herbs, seem quite insensible.

The organ of smell is a soft, vascular, porous membrane, furnished with papillæ, which is spread on the internal surface of the nostrils. On this membrane are distributed a great number of nervous fibres, which proceed chiefly from the first pair of nerves, and which pass through the ethmoid bone.

From

From the extreme tenuity of the epidermis, which involves the nerves and blood-vessels in this membrane, hemorrhage from the nose is more frequent than from any other part of the body.

In order to render this sense more acute, the internal cavity of the nose is variously contorted, and enlarged by a communication with several adjoining cavities, so as to increase very much the surface on which the sentient membrane is distributed. The cavities with which the nostril communicates are called sinuses; these are the frontal, which is seated in the frontal bone under the eye-brows; the ethmoid, which is a spongy cavity in the ethmoid bone; and the maxillary, which is chiefly formed in the maxillary bone, and lies immediately above the double teeth of the upper jaw. In animals, which smell more acutely, these provisions for enlarging the internal surface of the nostril are still more remarkable.

The membrane of the nose is defended and moistened by a viscid mucus; and so necessary is this to smelling, that when it is deficient, this sense is always imperfect. The nostrils are furnished with muscles, by which they are dilated, when, in order to distinguish scents more accurately, we draw in a large quantity of air. A considerable difference between smelling and tasting is, that the former is only acted on by the invisible effluvia of bodies which float in the air, the latter, by matter more condensed and visible. There seems, however, to be a greater similitude between tasting and smelling than between any two of the other senses; and when either of them is injured the other commonly suffers with it.

CHAP. XL.

HEARING, AND ITS ORGANS.

Description of the Ear.—Admirable Structure of this Organ for conveying and echoing Sound.—Manner in which the Pulses of Air are conveyed to the Ear.—Communication by the Eustachian Tube.—Reason why Persons who listen attentively open their Mouths.—The Membrana Tympani probably the great Instrument of hearing.

AS by the sense of smelling we distinguish certain particles floating in the air; so by that of hearing we discover the motions and vibrations of the air itself. The parts of the ear are distinguished into external and internal. The former of these divisions comprehends all those parts which we are able to observe without dissection, and which are separated from those of the internal ear by the membrana tympani, improperly called the drum of the ear, as it is only a membrane stretched before the entrance of the cavity which is properly the ear. The external ear, which from its resemblance to a certain sea-shell is called *concha*, is a cartilaginous funnel of an irregular oval form, moveably connected to the head by ligaments, muscles, and cellular substance. The muscles with which the ear is furnished, and which are much employed by quadrupeds, are of little or no use to man.

Different parts of the external ear are known by different names; its upper cartilaginous part is called

called the *ala* or wing, to distinguish it from the soft and pendent part below, called the lobe; its outer border or circle is called the *belix*, and the semi-circle within this, the *antibelix*. The moveable cartilage, placed immediately before the opening of the ear, is named the *tragus*, and an eminence opposite to this, at the extremity of the *antibelix*, is called the *antitragus*. The concha, becoming narrower, terminates in the *meatus auditorius externus*, the external auditory canal. Into this are continued the cutis and epidermis, which, as they enter it, become much thinner and more sensible, and are furnished with minute hairs, by which warning is given when any insect has found admittance, or when any injurious substance requires to be removed. This passage, and the *membrana tympani*, by which it is terminated, are moistened by a viscid secretion called the wax, which by stagnation becomes hard, and, when neglected, sometimes accumulates to such a degree as to occasion deafness. If we were to examine all nature for a contrivance proper for augmenting and echoing sounds with the utmost force and the greatest exactness, we should find the ear best formed for these purposes; by its admirable structure it receives sounds of all kinds, admits the greatest quantity in the smallest space, and echoes each back without confusion.

The external ear in different quadrupeds is differently framed, but always adapted to the creature's manner of life. In shape it commonly resembles the oblique section of a cone from near the apex to the basis. Hares, and such other animals as are daily exposed to injuries from beasts of prey, have large

ears directed backwards, their eye warning them of any danger before ; rapacious animals, on the other hand, have their ears placed directly forwards, as we see in the lion, cat, &c. The slow hounds, and other animals that are designed to hear most distinctly the sounds coming from below, have their ears hanging downwards, or their ears are flexible, because they move their head for the most part with greater difficulty than man. Man again, who must equally hear sounds coming from all quarters, but especially such as are sent from about his own height, has his external ear placed in a vertical manner, somewhat turned forward. In short, wherever we see a peculiarity in the make of this organ in any creature, we shall, with very little reflection, discover this form to be more convenient for that creature than another. The animal also has the power of directing the cone of the ear to the sonorous body without moving the head *.

The *membrana tympani* is a membrane consisting of several *laminæ*. Externally there is the epidermis, under this the vascular cutis, and, lastly, a dry, elastic, shining, and pellucid substance. These *laminæ* are connected by their cellular substance. The *membrana tympani* is never naturally perforated, and the passage of smoke from the mouth through the external ear, mentioned by some authors †, is fabulous, except, perhaps, in some cases, where a perforation had been accidentally made by violence or disease. By the action of particular muscles, the *membrana tympani* is pre-

* Monro on Comparative Anatomy.

† By Dr. Goldsmith in particular.

served in a degree of tension fit for receiving the impressions of the air. Under it runs a branch of the fifth pair of nerves, called the *chorda tympani*.

The *membrana tympani* is stretched before a roundish cavity of the *os petrosum*, hence called the *tympanum* or drum, and which is about seven or eight lines wide, and half as many in depth. This cavity is increased in the adult by a communication with the cells of the mastoid process, which do not exist in the *fœtus*. Within, the *tympanum* is lined by a moist and vascular membrane. The *tympanum* communicates with the cavity of the fauces, by means of the *meatus auditorius internus*, or Eustachian tube. This canal, which is partly bony and partly cartilaginous, begins by a very narrow opening at the anterior and almost superior part of the *tympanum*, increasing in size as it advances towards the cavity of the fauces, where it terminates by an oval opening behind the nostrils.

Within the *tympanum* are lodged the little bones of the ear, which are four in number, and from their form have received the following names.

1. The *malleus* or hammer.
2. The *incus* or anvil.
3. The roundish or oval bone.
4. The *stapes* or stirrup.

The body of the *malleus* is placed in the upper part of the *tympanum*, and a long process, called the handle, descends between the *laminæ* of the *membrana tympani*, where it is accurately fixed. It is articulated with the *incus* by means of two projecting ridges and a furrow between them.

The incus, which consists of a body and two legs, and is not unlike a tooth with a double root, exceeds the other little bones of the ear in size and strength. Its body is connected with the malleus; its shorter leg is placed at the entrance of the canal, which leads to the cells of the mastoid process; its longer leg takes the same direction with the handle of the malleus, to which it is attached by a ligament, and being bent inwards at its termination, receives the small oval bone, and by means of this is united to the stapes.

The resemblance of the stapes to a stirrup is so strong, that it can scarcely escape observation. Its head, which is formed by the union of its two legs, is hollowed for the reception of the little oval bone which connects it with the longer leg of the incus. The two legs of the stapes are bent nearly into a circle, and where they unite at the basis, cover the fenestra ovalis. The stapes is situated in a part of the tympanum, separated from the other parts by a particular membrane.

The stapes and malleus are each of them furnished with a little muscle, called, from the bones to which they belong, stapedius and tensor tympani. The first of these, which is the smallest distinct muscle in the body, arises from a little cavity at the posterior and upper part of the cavity of the tympanum, and its tendon is inserted at the back part of the head of the stapes. This muscle, which draws the stapes obliquely upwards, assists in stretching the membrana tympani. The other muscle is more remarkable, and as it operates like the former in stretching the membrana tympani, has more particularly

cularly obtained the name of tensor tympani. It arises from the cartilaginous extremity of the Eustachian tube, and is inserted into the back part of the handle of the malleus, which it helps to pull inwards, and by that means to stretch the membrana tympani.

That part of the ear which is situated behind the tympanum is called the labyrinth. The labyrinth is separated from the tympanum by a bony partition, and only communicates with it by means of two openings of nearly equal size, one of which is the fenestra ovalis, which is shut by the basis of the stapes, the other the fenestra rotunda, which is closed by a continuation of the membrane which lines the cavity of the tympanum.

In the labyrinth of the ear are situated the vestibule, the three semi-circular canals, and the cochlea.

The vestibule or porch is a cavity of an irregular roundish form, and is placed nearly in the center of the os petrosum, between the tympanum, the semicircular canals, and the cochlea. It is open on the side of the tympanum by means of the fenestra ovalis, and communicates with the upper portion of the cochlea by an oblong foramen, which is under the fenestra ovalis, from which it is separated only by a very thin partition.

The semicircular canals in the infant are formed of a distinct bony shell, but in the adult coalesce with the firm os petrosum, and are three in number, They form rather more than semicircles, and open at both ends into the vestibule. Only five open-

ings, however, are observed, since two of the canals are united at one termination.

The cochlea, so called from its resemblance to the shell of a snail, is formed by a conical nucleus and circumvolutions of thin bony lamellæ, which perform two complete circles and an half before they terminate at the apex. The canal of the cochlea is divided by a septum into two parts, which are called the *scalæ*; of these one begins from the fenestra rotunda, and is called the *scala tympani*, the other from the vestibule, and is called the *scala vestibuli*. The septum, which divides the *scalæ* from each other, is partly bony and partly membranous; it is deficient at the apex of the cochlea, where the cavities of the *scalæ* communicate. The bony lamella which separates the two canals is exceedingly thin, and fills about two-thirds of the diameter of the canal. The rest of the septum is composed of a most delicate membrane, which lines the whole internal surface of the cochlea. The *portio mollis* of the seventh pair of nerves furnishes a film of medullary matter to the whole internal surface of the vestibule, the semicircular canals, and the cochlea. Every part of the labyrinth is also supplied with an aqueous exudation, which is supposed to receive and propagate to the nerves the vibratory motions imparted by the air. When this fluid is collected in too great quantity, or is compressed by the stapes, it is supposed to escape through two minute canals or aqueducts, lately described by Dr. Cotunni, a physician of Naples. One of the aqueducts opens into the bottom of the vestibulum, and the other into the cochlea, near the
fenestra

fenestra rotunda. They both pass through the os petrosum, and communicate with the cranium; they are lined with a membrane, which is supposed to be a production of the dura mater.

The manner in which sound is propagated by pulses or undulations of the air has been fully, and, I trust, clearly explained in a preceding part of this work*; and from what has been now stated it will appear, that the ear is an organ admirably adapted for the reception of these impressions. Sound is, however, not merely conveyed by the external cavity of the ear; but by means of the Eustachian tube, the air finds admittance to the cavity of the tympanum, and the effect of the vibrating air, entering the mouth, may be conveyed to the ear. Hence we perceive the reason why persons who listen very attentively, and persons affected with partial deafness, open their mouths. When we breathe, the air received by this passage presses the membrana tympani outwards, and when we make a very full inspiration, as in yawning, this happens to such a degree as to prevent the impression of sounds from without, and occasions a temporary deafness.

Notwithstanding the labour of anatomists in tracing the intricate, singular, and very curious structure of the ear, they have never been able to discover the peculiar uses to which all the several parts are subservient. That the concha is designed to catch and reverberate to the auditory tube the vibrations of the air we are certain, from the analogous effect of a similar organ, the ear-trumpet. The membrana tympani, and the little bones of the

* See book v. chap. 10.

ear, are said to have been destroyed by disease, without depriving the patient of hearing. I cannot, however, suppose, that any part of the ear is unnecessary. It therefore seems reasonable to believe, that the *membrana tympani*, which is stretched across the passage to which the vibrations of the air are directed, is designed to receive them, for which use, by its elastic nature, it is admirably fitted. The *malleus* is attached to the *membrana tympani*, the *incus* to the *malleus*; the oval bone connects one leg of the *incus* to the head of the *stapes*, and the basis of the latter bone presses on the *fenestra ovalis*. From this structure we can scarcely draw any other conclusion, than that the tremulous motion excited in the *membrana tympani* by the impressions of the air are propagated through the contents of the *tympanum*, and imparted to those of the *labyrinth*, which are lined with a delicate nervous film, on which they may operate so as to produce the ideas of sound. When, however, we contemplate the various parts of the *labyrinth*, we cannot assign any reason for so complex a structure, and can only admire it as one of the wonders of creation. The analogy of other animals, indeed, instructs us in one particular, viz. that the *cochlea* is not essential to hearing, since birds and fish hear accurately without this part; but why it is not essential remains still a question.

To confess, however, that we are ignorant of the means by which we perceive sounds, is not more humble than we must also be with respect to the information derived from the other senses. Why a particular object affects our senses in a particular manner,

manner, is concealed from us by circumstances which our understandings cannot discover. As objects appear green when seen through a green glass, so is every object modified by the medium of the senses.

It is natural, however, to the human mind, to be desirous of perceiving things as they really are, and this may be an enjoyment provided for us in a future state, when we may regard the earth merely as a planet, and the sun as a fixed star; and when the mind, liberated from the fetters of the body, and endued with new faculties, may at once contract its attention to the laws which regulate the existence of the minutest animal, and extend its views to the comprehension of all the vast bodies which constitute the solar system.

C H A P. XLI.

S I G H T.

Description of the Eye.—Eyes of different Animals.—How Vision is performed.—How all the Parts of an Object are comprehended by the Eye.—An Image of every Object painted on the Retina of each Eye, and yet only one Object perceived.—Cause and Cure of Squinting.—The Sense of Sight limited.—By what Means we judge of Distance.—State of the Sight at different Ages.—Cautions for preserving the Sight.

THE eyes, those exquisite organs which raise the perceptive powers of the mind to some comparison with those of superior beings, and which in an instant of time admit impressions from an almost infinite variety of objects, are in their structure extremely simple. They are situated in those two cavities, the orbits, which afford them protection from a great variety of external injuries, and contain a quantity of fat, which answers the purpose of a soft cushion, on which they may rest, and perform their different motions with ease and safety. The globe of the eye is immediately covered by the eyelids, which are continuations of the common integuments of the body, doubled inwards, and attached to the eye, by which they produce what is called the tunica conjunctiva. Where the two eyelids are united together, they form the canthi, or angles of the eyes; that next the nose is called the internal large or inferior angle; the other, on the

the contrary, which is next the temples, is called the external small or superior angle. The edges of both eyelids are furnished with rims of cartilage called the tarfi; on the margins of these, which are called ciliary edges, are situated sebacious glands, which discharge an oily fluid for the purpose of preventing adhesion. The ciliary edges of the tarfi are furnished with eye-lashes. The chief use of these seems to be, to prevent dust, and other matters floating in the atmosphere, from falling into the eyes.

At the internal angle of the eye is situated the *caruncula lachrymalis*, which is a small reddish oblong body. This substance seems to be glandular. By the aid of a microscope we observe upon it a great number of small hairs, covered by an oily yellowish matter. On the globe of the eye, near this glandular body, is a semilunar fold formed by the *membrana conjunctiva*. This fold, which is called the *membrana semilunaris*, is shaped like a crescent, the two points of which answer to the *puncta lachrymalia*, which are the beginnings of a canal terminating in the cavity of the nostrils.

The surface of the eye is constantly moistened by a very fine limpid fluid, called the tears, which is chiefly, and perhaps wholly, derived from a gland, situated in a small depression of the *os frontis*, near the external angle of the eye. Its excretory ducts pierce the *tunica conjunctiva* just above the cartilaginous borders of the upper eyelids. As this fluid enters the eye at the superior angle, it naturally descends towards the inferior, and is also frequently spread over the surface of the eye by the motion of
the

the eyelids. When it arrives, after thus having washed the eye, at the internal angle, it is conducted by the *membrana semilunaris* into the *puncta lachrymalia*, which lead into the *sacculus lachrymalis*, from which it is ultimately discharged into the nose.

When the eye is irritated by any extraneous substance, the tears are discharged in greater quantity, and thus serve as a defence to this tender organ, and sometimes wash away the cause of irritation, or facilitate its removal. Affections of the mind also sometimes occasion an increased flow of tears; the efficient cause of this connection we cannot trace, but the final cause seems to be to excite sympathy, and urge the unfeeling heart to acts of mercy and benevolence.

The ball of the eye is a case of a globular form. It consists of three coats, an external one called the *sclerotica*, which is white and glistening like the tendon of a muscle; an intermediate one, abounding with blood-vessels, called the *choroides*; and an internal coat, called the *retina*, which is an extremely tender film or network, formed by the expansion of the optic nerve. This description, however, applies only to the posterior and lateral parts of the eye, for at the fore part of the eye, instead of the opake *tunica sclerotica*, we observe a projecting transparent circular part, continued from the *sclerotica*, which from its substance being transparent like horn, is called the *cornea*. This portion is somewhat more convex than the *sclerotica*, and represents the segment of a small sphere added to the segment of a greater, or, to express the same idea in more familiar language, it may be considered as resembling

resembling a convex watch-glass, fixed on the less convex surface of a watch case.

The tunica choroides extends from the back part of the eye as far as the termination of the sclerotic, where it is firmly connected by means of a white ring projecting inwards, and called the ciliary circle or ligament. From this edge proceeds a very fine weblike membrane or curtain, called the iris. Its difference of colour in different persons is a matter of common observation. In the middle of the iris is an opening which always appears black, and which is rendered narrower or wider by the contractile powers of the iris. This opening is called the pupil, through which the rays of light are admitted to the internal parts of the eye.

The tunica choroides is described by some authors as consisting of two laminæ. This description, however, applies much better to the eyes of some animals, particularly to those of sheep, than to those of man. Those who suppose the choroides to consist of two laminæ, describe the external one as terminating at the ciliary ligament, and the internal one as extending further to form the iris. The iris itself is described as consisting of two laminæ, and it is very certain that two sets of fibres may be observed. These are supposed to be muscular, and from the mobility of the iris there seems no reason to doubt of their being really so. Some of the fibres are orbicular, and lie round the pupil; others are strait, and extend from the circumference of the iris to its center. The iris has motions of such a nature, that the pupil is contracted on the approach of a strong light, and is dilated in proportion as the
light

light is less vivid. By this admirable yet simple contrivance, the eye adapts itself to the different proportions of light to which it is exposed. If the pupil was always as much contracted as it is when exposed to the light of noon day, a weaker light, such as that of the moon, could not be admitted with sufficient freedom to answer any useful purpose. On the contrary, if the pupil was immoveably dilated, we might take advantage of the scattered rays of light, but should be distressed and blinded by the glorious effulgence of the sun. When a strong light succeeds to darkness, we are under a necessity of closing the eye-lids, or of turning away the head, till the pupil has been accommodated to the change by the contractile powers of the iris.

The choroid coat is internally covered with a slimy substance of a dark colour, called the pigmentum nigrum. The epithet black, however, is not descriptive of this substance in every race of animals. On the contrary, in the ferret the pigmentum is white, and this circumstance enables that animal to see in the dark, a faculty well adapted to its habits and mode of life. In man, distinct vision in a full light is a more useful quality than the power of distinguishing objects where the light of day is excluded. The reason, therefore, of the black colour of the pigmentum is, probably, that those rays which pass the retina, which is a fibrous substance, may be absorbed, whereas, when it is of a light colour, many of them are reflected and strike the retina, thus increasing the power of vision where there is a deficiency of light, but producing too great an effulgence and glare in ordinary cases. This reflection is very obvious

vicious in the degree of illumination which proceeds from the eyes of a cat in a dark place*.

The posterior part of the iris is of the colour of a grape, and was therefore by the ancients called the uvea. The eye being, therefore, every where provided within, except at the entrance of the optic nerve, with a lining of a dark colour, becomes a camera obscura, and the light which is admitted through the pupil, and passes to the bottom of the eye, is not disturbed with light reflected from other surfaces.

The ball of the eye is filled with three substances, which differ from each other in consistence, but are all called humours of the eye; they are the vitreous, the crystalline, and the aqueous. See plate xv. fig. 1, and 2.

The vitreous humour was so called from a supposed resemblance to melted glass; it is a clear and gelatinous fluid, very much resembling the white of an egg. It fills about three-fourths of the globe of the eye, and extends from the posterior part of the eye as far as the ciliary ligament. It is contained in a fine transparent capsule or membrane, and being dexterously removed from the globe of the eye, preserves its consistence for some time, being supported by its capsule, but afterwards runs off, and the capsule shrinks by degrees. The thin capsule which surrounds the vitreous humour sends off a number of membranous processes into the vitreous substance, where they form cells, which communicate with each other, and afford a greater degree of firmness and tenacity to the whole mass.

* Hunter on the pigmentum of the eye. See his Animal Economy.

The anterior part of the vitreous humour is excavated for the reception of the crystalline. This body has the consistence of very firm jelly, and has the form of a lens more convex behind than before. It is most properly denominated the crystalline lens, and is invested with a capsule, which is derived from that of the vitreous humour, or at least connected with it. Steno observed, that the lens was composed of concentric lamellæ, and Zinn has discovered radiated streaks of a pearl colour, dividing it into little triangles. The colour and consistence of the crystalline humour varies at different ages. Till the age of thirty it is very transparent, and almost without any colour. It afterwards becomes yellowish, and that yellowness gradually increases. Till the age of twenty the consistence of the lens is generally uniform throughout; from this time it becomes hardest in the middle, and this hardness gradually increases, and extends towards the surface*.

The fore part of the eye is filled by a fluid transparent like the others, but as thin as water, and it is therefore called aqueous; this occupies all the space between the crystalline lens and the prominent cornea. The iris floats loosely in this fluid, and divides

* The crystalline lens in fish is completely spherical, and is more dense than in terrestrial animals. This difference is to be accounted for from the different refractive power of the medium in which they live. The rays of light, in passing out of one medium into another, undergo a refraction proportioned to the difference of their densities. As water, therefore, is a more dense medium than air, the eyes of such animals as inhabit the former must have a greater refractive power than those which live in the latter, for the production of distinct vision.

it into two parts called chambers, which communicate with each other through the pupil. The posterior chamber is that space contained between the posterior surface of the iris and the lens; the anterior is that between the anterior part of the iris and the cornea.

The eye receives its blood from the internal carotid artery. The optic nerve does not enter it immediately behind the pupil at its posterior part, but rather towards the nose, so that the distance between the pupil and optic nerve is greater when measured round the external side of the eye next the forehead, than when the internal surface is measured next the nose. At that part of the eye where the optic nerve enters, no sense of vision can be excited.

The muscles of the eye have been already described in another part of the work. For the human eye, see Plate XV. Fig. 1, and 2.

The father of the present Dr. Monro, of Edinburgh, has published, in his comparative anatomy, some excellent remarks on the variety in the eyes of different animals, than which no more striking instance can be produced of the wisdom and design which pervades creation.

‘All quadrupeds have, he observes, at the internal canthus of the eye, a strong firm membrane with a cartilaginous edge, which may be made to cover some part of their eye; and this is greater or less in different animals, as their eyes are more or less exposed to dangers in searching after their food. This *membrana nictitans*, as it is called, is however not very large in all these animals. Cows and horses have it

so large as to cover one half of the eye like a curtain, and at the same time it is transparent enough to allow abundance of the rays of light to pass through it. Fishes have a cuticle always over their eyes, as they are ever in danger in that inconstant element, the water. In this therefore we may observe a sort of gradation.

‘ All quadrupeds have a seventh muscle belonging to the eye, called *suspensorius*. It surrounds almost the whole optic nerve, and is fixed into the sclerotic coat as the others are. Its use is to sustain the weight of the globe of the eye, and to prevent the optic nerve from being too much stretched, without obliging the four straight muscles to be in a continual contraction, which would be inconvenient: at the same time this muscle may be brought to assist any of the other four, by causing one particular portion of it to act at a time.

‘ The next thing to be remarked is the figure of the pupil, - which is different in different animals, but always exactly accommodated to the creature’s way of life, as well as to the different species of objects that are viewed. Man has it circular, for obvious reasons: an ox has it oval, with the longest diameter placed transversely, to take in a larger view of his food: cats, again, have theirs likewise oval, but the longest diameter placed perpendicularly; they can either exclude a bright light altogether, or admit only as much as is necessary. The pupil of different animals varies in wideness, according as the internal organs of vision are more or less acute: thus cats and owls, who seek their prey in the night, or in dark places (and consequently must

must have their eyes so formed as that a few rays of light may make a lively impression on the retina), have their pupils in the day-time contracted into a very narrow space, as a great number of rays would oppress their nice organs; while in the night, or where the light is faint, they open the pupil, and very fully admit the rays. In the same way, when the retina is inflamed; a great number of rays of light would occasion a painful sensation; therefore the pupil is contracted: on the contrary, in dying people, or in a beginning amaurosis, it is generally dilated, as the eyes on such occasions are very difficultly affected, and in some measure insensible. See Plate XV. Fig. 3, 4, 5.

‘ The posterior part of the choroid coat, which is called tapetum, is of different colours in different creatures. For oxen, feeding mostly on grass, have this membrane of a green colour, that it may reflect upon the retina all the rays of light which come from the objects of that colour, while other rays are absorbed: thus the animal sees its food better than it does other objects. Cats and owls have their tapetum of a whitish colour; and for the same reasons have the pupil very dilatable, and their organs of vision acute: and we shall find, that all animals see more or less distinctly in the dark, according as their tapetum approaches nearer to white or black colour. Thus dogs, who have it of a greyish colour, distinguish objects better in the night than man, whose tapetum is dark brown, and who, I believe, sees worst in the dark of any creature; it being originally designed that he should rest from all kinds of employment in the night-time. The difference then of the colour of the tapetum, as

indeed the fabric of any other part in different creatures, always depends on some particular advantage accruing to the animal in its peculiar manner of life from this singularity*.

It was necessary, in a former part of this work, to notice the subject of vision, in describing the effects and phenomena of light †. The eye was then mentioned as a mere optical instrument, but after the particular description of that organ, which has now been given, a more particular investigation of the sense of sight seems to be required; and should the reader find any thing like repetition in what will now be submitted to him, his candour will, I doubt not, pronounce my apology for endeavouring to render as clear as possible a subject which is at once both important and difficult to be understood.

It has been sufficiently explained, that from every point of a visible object the rays, or rather pencils, of light are emitted or reflected in every direction; but to produce vision, it is necessary that they should be condensed or converged to such a point as to make a forcible impression on the retina. Thus from the luminous body A (Fig. 6.) the rays r, r, r are sent in various directions. Those which fall upon the transparent cornea C C are there refracted in such a manner as to enter the pupil at p , and in passing the crystalline lens or humour they suffer a second refraction, and are converged to a point or focus at the point a on the retina. Now it is evident, that if the rays could

* Monro's Comparative Anatomy.

† See book iii. chap. 6.

Fig. 1.

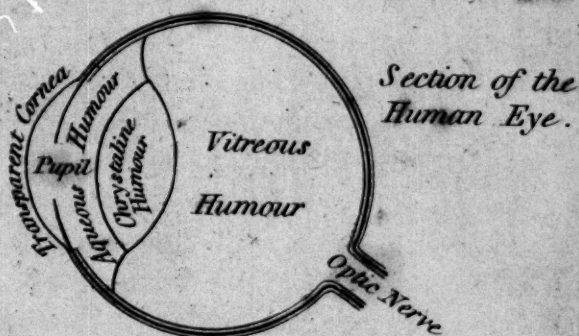


Fig. 2. Human Eye.

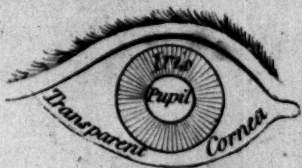


Fig. 3. Horse.

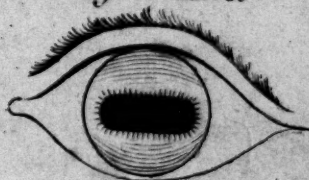


Fig. 4. Bird.



Fig. 5. Cat.

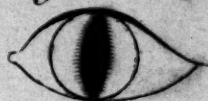


Fig. 6.

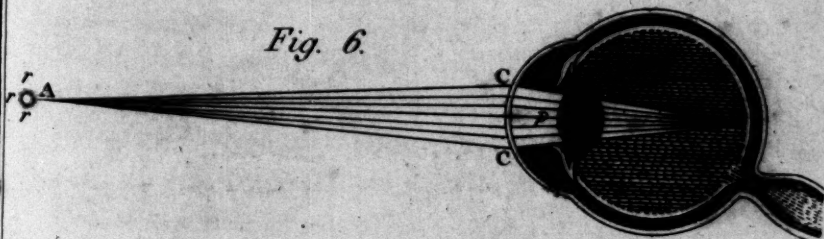
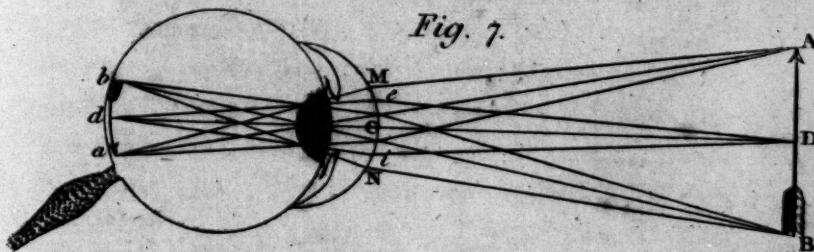
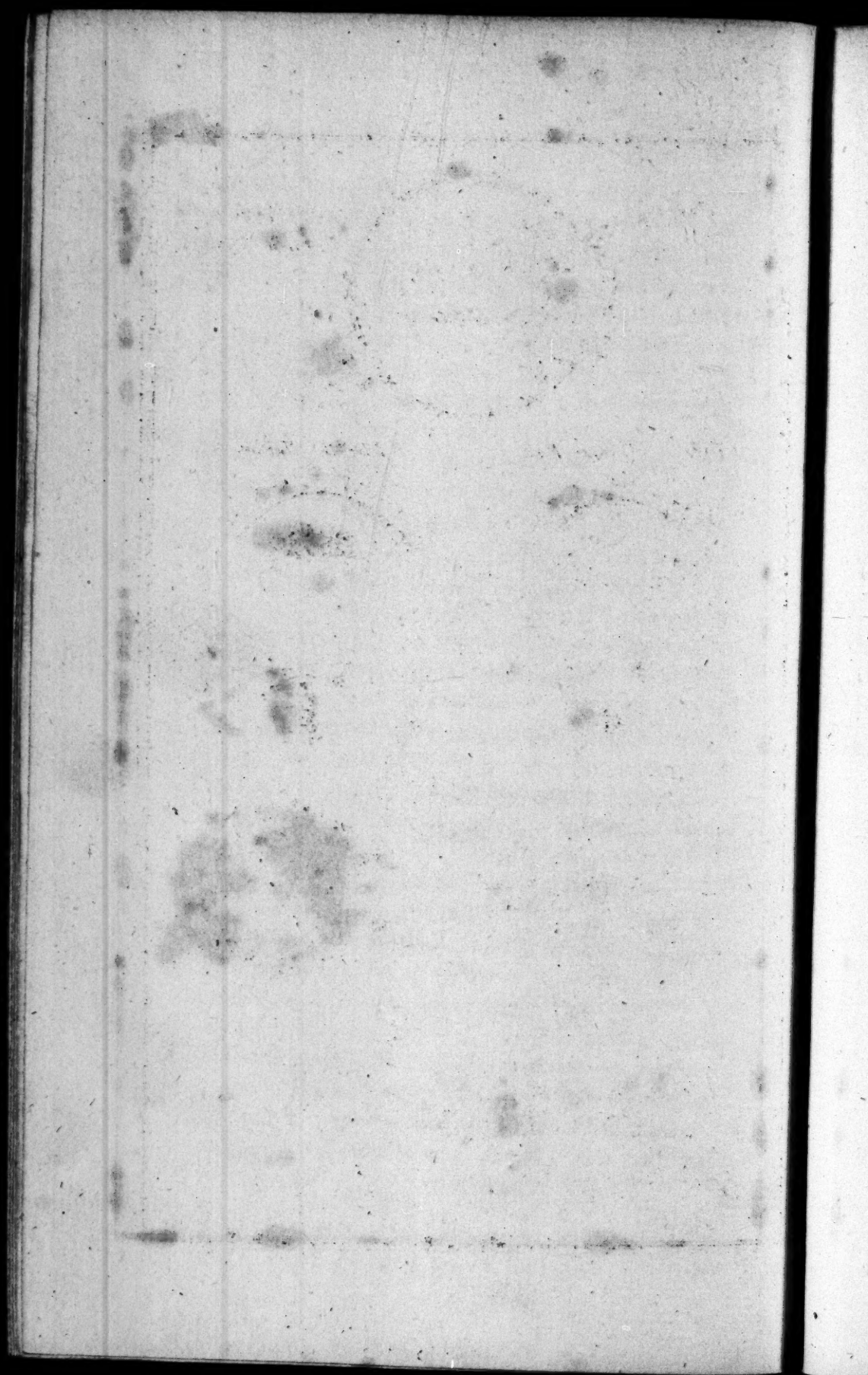


Fig. 7.





have passed the humours of the eye in their natural direction, that is in the direction of the cone or pyramid C, A, C, they would have made upon the retina a very extensive but feeble impression, such as we know by experience could not produce distinct vision; to obviate this it is appointed by the all-wise author of our existence, that by the force of the refraction which they suffer in the eye, they should form another cone opposed to the first at its base, and the apex of which is at *a*, and thus an impression sufficiently forcible to produce distinct vision is made on the retina.

In the preceding instance, the luminous body A was considered as a point, and what has been said of it will apply to *every point* of a visible object, which is capable of transmitting or reflecting to the eye a pencil or collection of rays. Thus we may easily suppose that from every point of the arrow A, D, B, (Fig. 7.) pencils of light may be transmitted; these, like all pencils or collections of rays coming from a point, will diverge, and will fall upon the eye in the form of cones or pyramids, such as A, M, C. from the point A; D, *e*, *i* from the point D; and B, C, N. from the point B. If the eye, therefore, is in a proper state, the divergent rays proceeding from the point D will be united together into one pencil or mass, such as they were when they first proceeded from the object, at the point *d*, upon the retina; the divergent rays, which fall more obliquely from the point A, will be united on the retina at the point *a*; and those which proceeded from B will, by the same rule, be converged and meet at *b*. Hence it is evident, that by means

of this refraction there are certain points at which the rays of light, after passing the pupil, cross each other, and the image which is formed on the retina is consequently inverted.

If the humours of the eye, through age or weakness, have shrunk or decayed, the cornea will then be too flat, and the rays not being sufficiently bent or refracted, arrive at the retina before they are united in a focus, and would meet, if not intercepted in some place behind it, as in Plate XVI. Fig. 8. They therefore do not make an impression sufficiently forcible, but form an indistinct picture on the bottom of the eye, and exhibit the object in a confused and imperfect manner. This defect of the eye is therefore remedied by a double convex lens, such as the common spectacle glasses, which, by causing the rays to converge sooner than they otherwise would, afford that aid to this defect of nature which the circumstances of the case may require, the convexity of the glass being always proportioned to the deficiency in vision.

If, on the contrary, the cornea, is too convex, the rays will unite in a focus before their arrival at the retina, as in fig. 9, and the image will also be indistinct. This defect is remedied by concave glasses, which cause the rays to diverge, and consequently, by being properly adapted to the case, will enable the eye to form the image in its proper place.

As the direction in which the rays cross each other bears a due proportion to the angle in which they are transmitted from the object to the eye, it is evident that the image formed upon the retina will

will be proportioned to the apparent magnitude; and thus we have our first ideas of the size and distance of bodies, which, however, in many cases are corrected by experience. The nearer any object is to the eye, the larger is the angle by which it will appear in the eye, and therefore the greater will be the seeming magnitude of that body. This fact it will not be difficult to explain. Suppose the object H K (see Fig. 10.) to be at a hundred yards distance, it will form an angle in the eye at A. At two hundred yards distance, the angle it makes will be twice as small in the eye at B. Thus to whatever moderate distance the object is removed, the angle it forms in the eye will be proportionably less, and therefore the object will be diminished in the same proportion.

- From some late experiments made by Dr. Hofsch and Mr. Ramsden, it appears, that the power of changing the focus of the eye, and adapting it to different distances, does not reside in the crystalline lens, but in the cornea: that the cornea is composed of laminæ; that it is elastic, and capable of being elongated one eleventh of its diameter, and of contracting to its former length by its own exertions; and lastly, that the tendons of the four strait muscles of the eye are continued to the edge of the cornea, and terminate or are inserted in its external lamina. By the same experiments it was found, that in changing the focus of the eye from seeing with parallel rays to a near distance, there is a visible alteration produced in the figure of the cornea, which renders it more convex; and the alte-

ration by which the cornea is brought back to its former state is equally visible *.

Artificial eyes are sold by the opticians, in which all the humours are made of different kinds of glass, and may be separated at pleasure. At the back part, where the retina is supposed in the natural eye to receive the converged rays, is placed a piece of ground glass, where the image from the opposed objects is painted in an inverted position, as in a camera obscura. The same effect may be produced with a natural eye, and the nature of vision may be thus experimentally demonstrated: if a bullock's eye is taken fresh, the posterior coats dexterously removed even to the vitreous humour, and if a piece of white paper is then placed at the part, the image of any bright object which is placed before the eye will be seen distinctly painted on the paper, but in an inverted position.

It has been a matter of much doubt and dispute by what means it happens that we see every object in its natural upright position, when we know it to be inverted on the object of sensation. To this the most satisfactory answer that can be given is, that we do not see the picture which is formed at the bottom of the eye, but the object itself. The picture, or rather the impression made on the retina, is the means of seeing, and therefore it does not appear of material consequence on what part of the retina the impression is made. We in fact see the image in the direction of that ray which conveys to us the sensation, or rather in the direction of the axis of that pyramid, which a pencil of di-

* Phil. Trans. for 1795, Part 1.

Fig. 8.

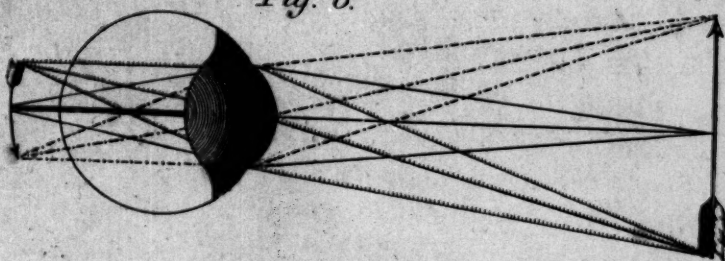


Fig. 9.

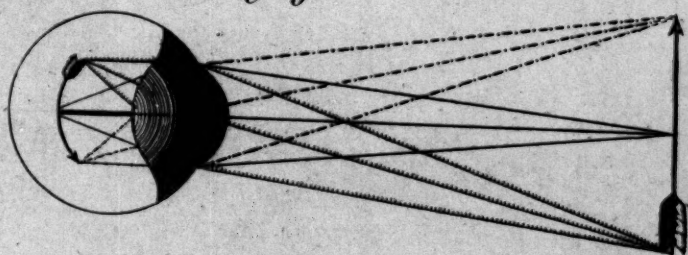


Fig. 11.

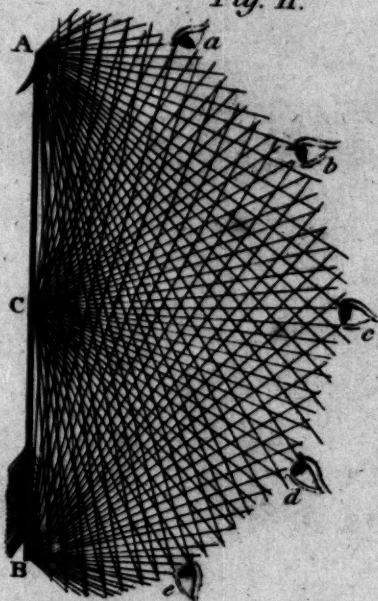
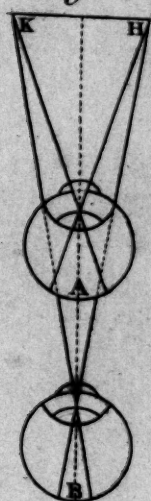
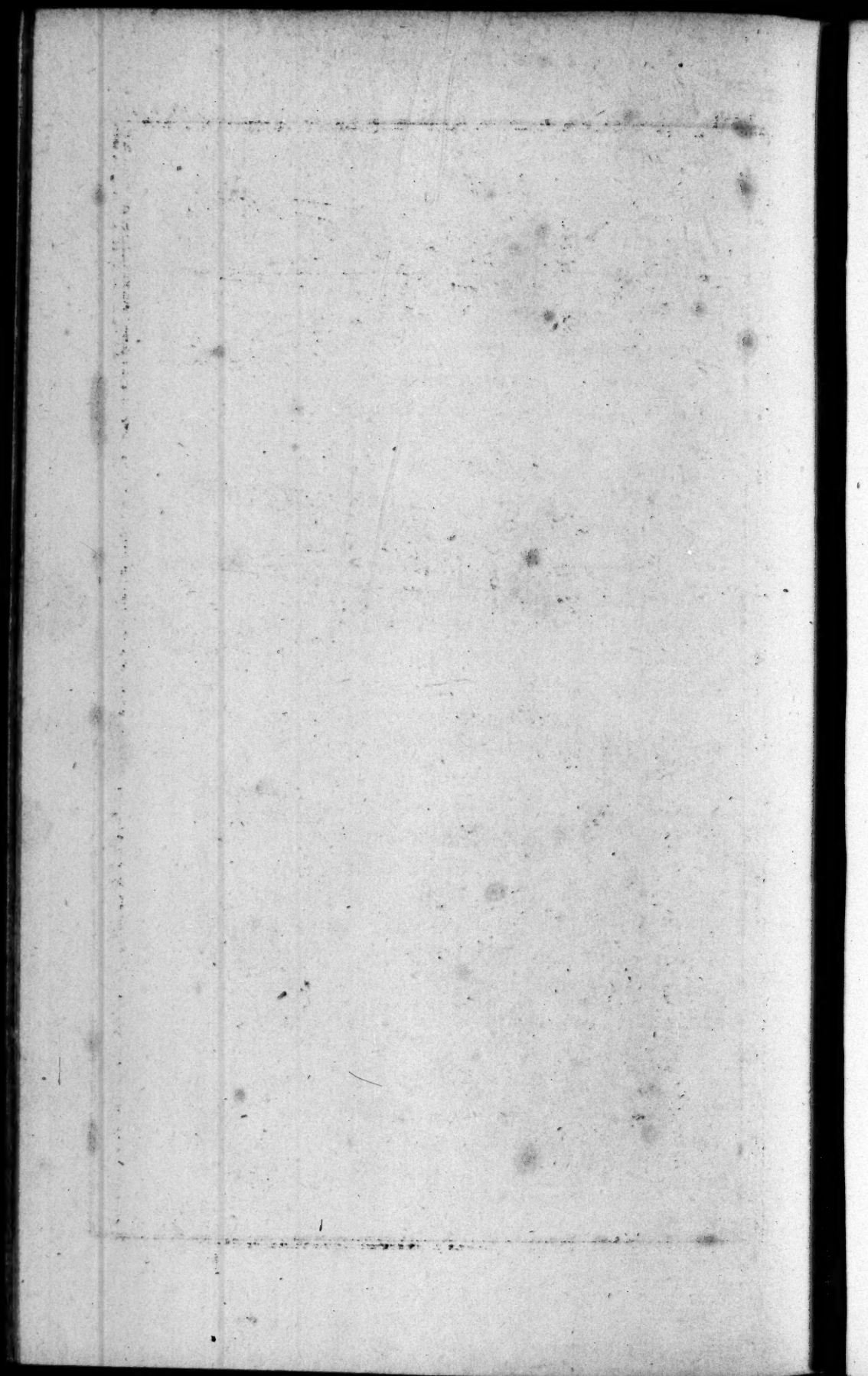


Fig. 10.





vergent rays forms in proceeding from any point of an object. Thus in Fig. 7. we see the point of the arrow (which is indeed depicted in the lower part of the eye) in the direction of the line *a*, *A*, that is, in its proper upright position. On the contrary, we see the other extremity of the arrow (which is painted on the superior part of the retina) in the direction of *b*, *B*, that is at the lower end of the object. However, therefore, the image, which is formed, may appear inverted to a person inspecting a natural eye, as in the preceding experiment, still the eye itself discerns the object in its proper and natural position.

As the rays of light are emitted or reflected from a visible object in all directions, it is evident, that some of them from every part of it must reach the eye. Thus the object *A*, *B*, *C* (Fig. 11.) is visible to an eye in any part, where the rays *A a*, *A b*, *A c*, *A d*, *A e*, *B a*, *B b*, *B c*, *B d*, *B e*, *C a*, *C b*, *C c*, *C d*, and *C e* can come. But though rays are reflected from every point of the object to every point of the circumambient space, yet it is evident, that only those rays which pass through the pupil of the eye can affect the sense; these rays give also the idea of different colours, according to the properties of the bodies which transmit or reflect them, upon the principles formerly demonstrated.

It is very difficult to explain how it happens that two distinct images are painted upon both eyes, and yet that we only perceive a single object. This difficulty has been attempted to be solved by having recourse to the power of habit; but I confess

feels I cannot help being of opinion with Dr. Reid, that the correspondence of the centers of the two eyes, on which single vision depends, does not arise from custom, but from some natural constitution of the optic nerves. The case of the young man born blind, who was couched by Mr. Cheselden, and who saw singly with both eyes, immediately upon receiving his sight, is very properly adduced by that respectable author in favour of this supposition. He also found, that three young gentlemen, whom he endeavoured to cure of squinting, saw objects singly, as soon as they were brought to direct the centers of both eyes to the same object, though they had never been used to do so from their infancy; he remarks too, that there are cases in which the fullest conviction of an object being single will never make the object appear so, even by the longest practice, as in the case of looking through a multiplying glass*.

In those who squint, the distance between the two pupils is considerably less than in other persons, for when the pupil of the undistorted eye is seated in the middle of the aperture, as in looking directly forwards, the pupil of the other eye is drawn close to the nose, so that the two axes are never pointed at the same object, though the muscles so far act in concert with each other, as to move both eyes the same way at the same instant of time. Dr. Jurin observes, that this vicious habit may easily be contracted by a child, if he is laid in his cradle in such a position as to perceive the light with one eye only.

* Reid's Inquiry into Human Mind, p. 267.

The most common cause of squinting is, however, an inferiority in the sight of one of the eyes, Dr. Reid asserts, that having examined above twenty persons, who squinted, he found in all of them a defect in the sight of one eye. Four of them only had so much of distinct vision in the weak eye as to be able to read with it, while the other was covered; the rest saw nothing distinctly with the defective eye*.

When the eyes are equally good, we see with both eyes more distinctly than with one, by about a thirteenth part; but when the eyes are unequal in their powers, objects appear less distinct with both eyes than with one. It is no wonder, therefore, that such persons should chuse to make use of one eye only, and to turn the other aside; the weak eye, in this case, is generally turned to the nose, because in that situation the direction of its axis is as distant as possible from that of the good eye; and besides this, the nose conceals many objects from its view.

This is, however, not the only cause of squinting; it is sometimes, though rarely, the effect of habit, as was intimated respecting children being laid in the cradle with one eye turned from the light, or covered. When the eye that squints is turned outwards towards the temples, that cast of the eye is commonly the mere effect of habit.

If the eyes differ much in point of goodness, the cure will be extremely difficult. When they do not materially differ in this respect, the proper and natural cure is to cover the good eye for some

* Reid's Inquiry into Human Mind, p. 253.

time;

time; for in this case the distorted eye is obliged to act, and to turn itself directly to objects, which in a little time becomes natural and easy to it. Even a very weak eye acquires strength by exercise; persons whose squinting seemed almost incurable, having covered their good eye for a few minutes only, have been themselves surprised to find the strength that their bad eye had acquired by exercise even for that short period. When the squint has proceeded entirely from a vicious habit, a cure has been effected by covering the good eye for a fortnight only*.

The powers of this sense are limited, as well as those of every other sense and faculty of man.

1st. The sight is very limited with respect to bodies in motion; for with a certain degree of velocity, as that of a cannon ball through the air, they are not visible, unless very luminous.

2d. The same effect is exemplified by the experiment of whirling a lighted coal, as was already intimated.

3d. If two objects unequally distant move with the same degree of velocity, the more remote will appear the slower. 4th. A visible object moving with any velocity appears to be at rest, if the space described in a second of time is invisible to the eye. Thus a near object, as the index of a clock, moving slowly, or a remote one, as a planet, moving swiftly, appears to be at rest. 5th. It is well known, that when the eye is proceeding straight forward, as in a boat at sea, a lateral object, either

* Reid's Inquiry into the Human Mind, p. 253.

at rest, or moving not so fast, appears to move the contrary way. 6th. If, however, the object is at a very great distance, it will seem to go the same way, as when a person runs by moonlight, the moon appears to accompany him. 7th. If two or more objects move with the same velocity, and a third remains at rest, it will appear in motion while the moving ones seem at rest; this is exemplified by the moon and the clouds.

There are six natural methods, by which we judge of the distance of objects from the eye. 1st. By the angle which is made by the optic axes. For want of this direction it has been observed, that persons who are blind of one eye frequently miss their mark in pouring liquor into a glass, &c. 2ndly, and I think most generally, by the apparent magnitude of objects. By depending upon this method we are very frequently deceived in our estimates of distance by any extraordinary large objects, as in travelling to a great city, church, or castle, we fancy them nearer than they really are. This furnishes us also with a reason why animals and other small objects seen contiguous to large mountains appear exceedingly small; for we imagine the mountain to be nearer to us than it actually is. On the other hand, when we look down from a high building, the objects beneath us appear much smaller than they would at the same distance on the level ground; the reason is plainly, because we have no distinct idea of distance in that direction, and therefore judge by the impressions upon the retina, whereas custom has corrected our judgment in the other case. The third method of determining the distance
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of objects is by the force and vividness of the colours, and the fifth is analogous to it, namely, by the different appearance of the minute parts. When these appear distinct, we judge the object to be near, and the contrary when they appear faint or confused. 6thly, We are assisted in judging of the distance of any particular objects, by the other objects which are interposed. On this account, distances upon uneven ground do not appear so great as upon a plain; for the valleys, rivers, and other objects that lie low, are many of them lost to the sight. This too is the reason why the banks of a river appear contiguous when the river lies low and is not seen*.

In children the pupil is usually more dilated than in grown persons. The reason of this appears to be, that in childhood the cornea is more flexible, so as to be very easily bent into any curvature necessary for distinct vision, and consequently the pupil has less occasion to contract. In grown persons the cornea is stiffer, they have therefore more necessity to contract the pupil. In elderly persons the cornea grows still more rigid; for this reason they are obliged sometimes to hold the candle between the eye and the paper on which they read; and their doing so is a direct indication that they begin to want spectacles†.

Children read much nearer than grown persons, both because their eyes are smaller, and because their cornea is more flexible. That elderly per-

* Essay on Vision, quoted by Priestley.

† Porterfield on the eye, quoted by Priest. Op. Per. 6. f. 12.

sons see better at a great distance than younger persons is generally allowed.

It is a certain and very important fact, that long sightedness may be acquired, for countrymen, sailors, and those that are habituated to look at remote objects, are generally long sighted, want spectacles soonest, and use the deepest magnifiers; on the other hand, the far greater part of the short sighted are to be found among students, and those who are conversant with small and near objects; every one becoming expert in that kind of vision which is most useful to him in his particular profession and manner of life.

Mr. Adams, in his very useful essay on vision, has given some rules for the preservation of the sight, which, for the benefit of the studious reader, I have thought it proper to insert.

1st. Never sit for any length of time in absolute gloom, or exposed to a blaze of light. From this rule may be deduced the impropriety of going hastily from one extreme to the other, whether of darkness or of light, and it may be inferred that a southern aspect is improper for those whose sight is weak and tender. 2dly. Avoid reading a small print. 3dly. Do not read in the dusk, nor, if the eyes are disordered, by candle light. 4thly, The eye should not be permitted to dwell on glaring objects, more particularly on the first waking in the morning. 5thly. The long sighted should accustom themselves to read with rather less light, and somewhat nearer to the eye than usual, while those who are short sighted should use themselves to read with the book as far off as possible.

CHAP. XLII.

THE GESTATION AND BIRTH OF ANIMALS.

Varieties in the Production of Animals.—Proportion of Males to Females.—Growth of the Fœtus.—Oviparous Animals.—Mode of Existence before Birth.—Weight of a new born Infant.—Miscellaneous Calculations concerning the Proportion of Births to that of Deaths in Infancy, &c.

WE have hitherto been occupied in considering the functions which relate to the existence and welfare of animals, let us now direct our attention to those which, amidst the decay of individuals, preserve the continuance of the species.

Among the most minute and imperfect animals, there are some which may be multiplied from fragments of the same species, as the polypus; others grow from the bodies of their parents, and are in due season set at liberty to seek nourishment for themselves; some animals, at a certain period of their existence, naturally divide into several parts, each of which afterwards becomes a whole animal of the same race.

As we ascend in the scale of animal existence, a difference of sex presents itself as a leading distinction. We find some races of animals, of which every individual is possessed of both male and female organs; others, among which a single female breeds for a whole community, and among which there are very few individuals possessed of sexual organs.

organs. In general, however, about half the individuals of a species are males and half females.

It is in some measure foreign to the objects of the present work to enter on those theories with which philosophers have amused themselves and their readers concerning the generation of animals. Independent of the indelicacy of the subject, there is another strong objection to their introduction here; since these theories rest upon no other foundation than conjecture, and some fallacious, and, I think, delusive microscopical observations. I shall, therefore, content myself with referring the reader to the natural history of the Count de Buffon, and for a direct contradiction of his theory to the Abbe Spalanzani. The former of these philosophers has derived the principle of animal existence from the male, and the latter from the female. The generation of fishes appears, indeed, greatly to favour the theory of Spalanzani, for in that instance at least, the rudiments of the young animals appear to be contained in the eggs or roe, which the female fish first deposits; and the milt which is afterwards deposited by the male appears only to excite them into action and growth. If we admit thus much of his theory, however, we must attend him a step further, and suppose that every female ovum in the ovarium of a female must itself contain ovaria and ova, and by extending the same idea we must be led to conclude, that the rudiments of all the animals, which have existed, do exist, or ever will exist, were originally contained in the ovarium of the first female of the particular species to which they respectively belong. This has been therefore called the theory of involu-

tion, and has been supposed equally applicable to animals and vegetables.

In the process of generation, the first marks we see, after impregnation, of the future progeny, is a minute being without limb or feature, connected by a cord to the internal surface of the uterus, and surrounded by very thin membranes. It seems formed, however, of two masses joined together, the larger of which is the head and the smaller the body. As the foetus advances in growth the body acquires a larger size with respect to the head, small protuberances make their appearance on the body, which are the future limbs, and the features begin to manifest themselves. In this manner the foetus, gradually acquiring a more determinate structure, and more evident marks of the species to which it belongs, is at length disengaged from the mother. In different species there is great variety in the perfection of the animal at the time of birth; the young of the human species is, perhaps, the most backward of any in this respect; for a child, when six months old, is not so able to provide for itself as a horse or an ass at the age of as many days.

In many races of animals it should be observed, particularly in birds, the growth of the foetus takes place out of the body of the mother. This is indeed the case with all animals which spring from eggs, and in which we have a very favourable opportunity of observing the progress of the foetus from its first appearance till it has acquired that state of perfection at which it is hatched. During the whole period of its growth it is supported by a limited quantity
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of nourishment contained within the egg-shell, and which is that part of the egg called the yolk.

The human foetus is surrounded with three membranes; the external of these is vascular, and is called the spongy chorion; the middle coat, called the media or true chorion, and the internal one, called the amnion, are not so. Mr. Hunter has found the spongy chorion to consist of two layers; that which lines the uterus he calls *membrana caduca* or *decidua*, because it is cast off after delivery; the portion which covers the ovum, *decidua reflexa*, because it is reflected from the uterus upon the ovum. The *membrana decidua* is, according to Mr. Hunter, perforated with three foramina, viz. two small foramina, corresponding to the openings of the Fallopian tubes at the fundus uteri, and a larger one opposite its cervix. The *decidua reflexa* becomes more thick and vascular as it approaches the placenta, and constitutes its maternal part.

The foetus appears floating in a transparent fluid contained in the amnion, suspended by the umbilical cord, and the head, being the largest part, and the insertion of the umbilical cord being at a considerable distance from it, falls lowest; a circumstance very necessary to safe and easy delivery. The foetus, when it has nearly obtained its growth, is curled up in an oval form; its back is round, and turned towards one side of the mother, making that side more protuberant; its chin is pressed against its breast; with its arms it embraces its knees, and its heels are close to its buttocks. A most curious but somewhat complicated branch of the animal œconomy, is the means which nature employs for carrying on the

nourishment of the *foetus*. I have already mentioned the umbilical cord, which connects the *foetus* to the uterus. One end of this cord is connected to the substance called the placenta, and the other enters the navel of the *foetus*. The placenta is a spongy substance as broad as the crown of a hat, and about two fingers in thickness, and is commonly attached to the upper part of the uterus. The outer surface of the placenta is soft, tender, and spongy, and commonly bloody, on account of its separation from the vessels of the uterus. Its internal surface, where it is covered by the membranes, is firm, glossy, and beautifully marked with the ramifications of blood-vessels. On the outside the blood-vessels can scarcely be observed, as they are there very minute. On the outside of the placenta there is also an appearance like a division into lobes. The umbilical cord is generally inserted, not into the middle, but towards the edge of the placenta, which facilitates its separation after delivery. With the placenta, as has been supposed, the arteries of the uterus have a communication, by which, in the first periods of gestation, the *foetus* receives a serous fluid, and in the later periods a large quantity of blood.

It has also been taken for granted, that the arteries of the umbilical cord communicate with the veins of the uterus, and that thus a circulation of fluids is maintained between the *foetus* and the mother. Mr. Hunter, however, after numerous experiments, has adopted a different opinion. By a variety of trials by injection he finds, that fluids thrown into the vessels of the umbilical cord never get into those of the uterus; and on the other hand, those thrown
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into the vessels of the uterus find no admission into those of the umbilical cord ; he therefore concludes, that the human placenta, as well as that of quadrupeds, is a composition of two parts intimately blended, viz. an umbilical or infantile portion, and an uterine portion. The former, by maceration, is found to consist of the ramifications of the vessels of the umbilical cord, the other Mr. Hunter considers as an efflorescence of the internal surface of the uterus, which forms a membrane, sending numerous processes into the substance of the placenta ; this latter is the membrana decidua. Mr. Hunter does not pretend to specify the nature of the union between these two portions of the placenta.

The veins of the placenta unite into a single trunk, which, leaving the placenta, enters the navel of the foetus. Two arteries, which are continued from the internal iliac arteries, pass out at the navel of the foetus and enter the placenta ; and these, with the vein above mentioned, constitute the umbilical cord. By means of these arteries and veins, a communication is maintained between the foetus and the placenta. The umbilical vessels do not run in a direct course, but both the arteries and the vein are mutually twisted about each other. The umbilical cord passes from the foetus to the placenta, through the *liquor amnii*. The winding course of these vessels, and the elasticity of the substance which surrounds them, protect them in a great measure from the bad effects which would otherwise happen, from their being stretched or pressed, which might put a stop to the circulation. Besides these vessels, however, there is another in brutes, called the urachus,

which conveys the urine from the bladder to a vessel called the allantoides. In the human species, both the urachus and the allantoides are wanting.

There is, indeed, in the human foetus, something like an urachus, which goes from the bladder of the foetus to the navel, between the umbilical arteries, but it seems to be of no use, as it does not communicate with the bladder.

The umbilical vein, after it has entered the body of the foetus, divides into two branches, one of which enters the vena portarum to be distributed in the liver; the other, which is called the ductus venosus, carries its contents to the left vena cava hepatis, which terminates in the great vena cava; and that part of the blood which passes through the liver also arrives at the vena cava. From the vena cava the blood passes into the anterior auricle, whence there is a passage into the posterior auricle, which is closed up after birth, but which now turns the greater part of the blood received by the anterior auricle, from the anterior to the posterior cavities of the heart. A considerable quantity of blood, however, notwithstanding this passage, does pass into the anterior ventricle; but all the blood which is received by the anterior ventricle is not sent to the lungs, which before birth are too much condensed to transmit so large a quantity; part of it is turned aside by a vessel called the ductus arteriosus, which passes from the pulmonary artery to the aorta. Thus, besides the blood which escapes passing through the lungs by means of the passage from the anterior to the posterior auricle, a second portion escapes by the vessel which leads from the pulmonary artery to the aorta,

aorta, so that perhaps not more than a sixth part of the blood which passes through the rest of the body passes through the lungs before birth, whereas, after these passages are closed, every drop which is circulated in the body must necessarily circulate also through the lungs. These passages, which are peculiar to the foetus, from causes not ascertained, close up very quickly after birth. The blood is returned from the foetus by the arteriæ umbilicales, which are the internal iliac arteries of the adult, but which in the foetus pass out at the navel, and are continued to the placenta.

The foetus, which in the early periods of gestation was almost all head, is still at the time of birth of very different proportions from those of the adult body; the head is remarkably large, and the lower extremities remarkably small. The growth of the foetus in the uterus is by no means uniform. The weight of children, when born at the full time, varies from something more than four pounds to a little more than eleven. By far the greater number weigh from five to eight pounds, *avoirdu-pois*. At the end of the third month, the bulk of the foetus, with the membranes and placenta, is very inconsiderable, as is seen in abortions, which are most frequent at this period of gestation. During the course of the fourth month the uterus becomes too large to remain within the pelvis, and rising into the abdomen, gives some slight degree of protuberance. The foetus now increases much faster than before; but the principal part of its growth is performed during the three last months of gestation, when the uterus at length rises as high as the sto-

mach, pressing the intestines towards the backbone. The distended uterus is now stimulated to contraction, and the pains of child-birth are succeeded by the effusions of maternal fondness.

It appears from a very accurate register, kept in the Lying-inn Hospital at Dublin, that the proportion of children, is about *nine* males to *eight* females ;—children dying under *sixteen* days old, as *one* to about *six and an half* ;—children still-born, as *one* to *twenty* ;—women having twins, as *one* to *sixty* ;—women dying in child-bed, as *one* to about *eighty-seven*.

There is, however, a greater mortality of male children, owing, as Dr. Clarke supposes, to their greater size, and particularly to the size of the head, which becomes injured in parturition, and consequently affects the health ; and the proportion is reduced to quite equal before the age of puberty.

If every mother in a great city was obliged to suckle her own child, the proportion would be *one* good nurse in *five* ; and in the country, not *one* bad nurse in *ten* *.

* Clark's Observations, Phil. Tr. 76.

CHAP. XLIII.

THE GROWTH AND DECLINE OF THE BODY.

Increase of the Body before and after Birth.—Disproportion of the Parts decreases with Growth.—What Parts first cease to increase in Size.—Youth.—Manhood.—First Symptoms of Decline.—At what Period old Age generally commences.—Symptoms of Age.—Causes why the Human Frame cannot be of long Duration.

FROM the time of conception till birth, the growth of the body proceeds in an accelerated or increasing proportion, that is, the growth in the sixth month, for instance, is greater in proportion than in the fifth; from birth till manhood it is gradually less and less, in other words, the growth of the second year is less in proportion than that of the preceding, and so of all the succeeding years.

The reason commonly assigned for the latter of these facts is, that the fibre becoming less distensible from an increase of solidity as we advance in age, our growth is consequently less rapid. But if the rapidity of growth was proportioned to the laxity of fibre, the foetus ought to increase most rapidly immediately after conception, and more slowly as its texture becomes more firm. The contrary of this, however, is found to be the fact, since, in the early periods of gestation the increase of the foetus is very slow, and its growth is continually accelerated till the birth. From this statement it must be concluded, that
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laxity of fibre is only one among other causes which favour the increase of the body. As the body advances in growth, its disproportions are gradually lost; the head increases more slowly, and the lower extremities with more rapidity. The head indeed ceases to grow much sooner than the other parts; for these, and particularly the thorax, seem to gain size and strength for several years after the head has arrived at its utmost dimensions.

At the age of fifteen or sixteen years, sooner in females than in males, and sooner in warm countries than cold, the signs of puberty begin to manifest themselves, and several changes now take place in the body, which it would be improper to state.

When the body has attained its full growth and strength, it does not immediately decline, but remains in a state of nearly equal vigour till between forty and fifty years of age. At this time the body begins sensibly to lose its agility, and the approaches towards old age, which had hitherto been insensibly going on, now begin to manifest themselves.

But though the body has now lost considerably of its agility, yet in persons of good constitutions, and who have not been remarkably intemperate, its strength remains pretty entire. After the age of fifty, however, the decline of body becomes much more apparent; there is no longer that spring and vigour of motion; and labour becomes more irksome and painful. From the age of sixty to that of seventy the health is frequently pretty good, but the strength fails considerably. Threescore and ten years is the age of man; and though there may be some

some remarkable instances to the contrary, yet, in general, existence protracted beyond this period is sorrow and misery.

In the whole progress of life the body is continually becoming less vascular. The vivid bloom of youth, which is owing to the ramifications of minute arteries in the skin of the cheeks, subsides into the moderate hue of middle life, and this into the wrinkled and shrunk appearance of old age. Similar changes are taking place in other parts of the body, and the coats of the arteries gradually becoming thicker and stronger with respect to those of the veins; these latter become more distended, and the livid hue of venous plethora succeeds to the vivid tint of the arterious. A disposition to solidity invades the body in the progress of life, and that which in the child was pliant cartilage, becomes in the old man brittle bone.

The quantity of earth in the composition of the different parts of the body is continually increasing; the muscles become insensible to the usual stimuli; the vigour of the circulation is diminished; and in the few, the very few, who escape the numerous pitfalls of disease and accident, this rigidity and insensibility increasing, necessarily puts an end to existence.

That modern discoveries, or the improvement of the medical art, should be able to protract for any considerable period our mortal existence is a notion that will only be entertained by those who are ignorant of the physiology of the animal frame, and indeed of every other branch of science. It is the natural consequence of extensive knowledge to
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abate our confidence; while impudence, dogmatism, and vain and visionary speculation, are the genuine offspring of ignorance. Medical skill may indeed be successfully applied in occasionally arresting the progress of those diseases, which might otherwise prematurely interrupt our mortal career; yet even in these instances, those who have studied most, and practised most, will be the most sensible of the impotence of human knowledge in this important art; but he who is at all acquainted with the delicate and fragile texture of the human frame must be abundantly sensible, that it is a fabric which was not meant to endure for ever.

In the gradual decline of life, to which all must submit, let us earnestly embrace that consolation which religion affords us. That which sweetened the cup of death to Socrates is through life the cordial of the christian; it is a consideration that will moderate prosperity, and will deprive adversity of its most poignant sorrows; it will cheer us in life, and at the hour of death it is the only circumstance that can impart a ray of comfort to the human soul.

BOOK X.

OF THE HUMAN MIND.

CHAP. I.

OF THE STUDY OF THE HUMAN MIND.

Our Knowledge of Mind limited.—Confused by Metaphysics.—Plan of this Inquiry.—The First Part respects the Instruments and Modes of Action of the Human Mind.—The Second, the Springs or active Powers.—The Third, the most important Questions in Morals, &c.

“**K**NOW thyself,” is a saying of great antiquity, and an author, whose sentiments are deservedly converted into maxims, has asserted, that “the proper study of mankind is man.” It is, however, a circumstance sufficient to mortify the pride of reason, that even on the subject most interesting to us, we must be content with a limited portion of knowledge; we must not extend our expectations too far. Even with respect to our own minds, there are some points which appear to be removed beyond the reach of our researches, while others are, perhaps unnecessarily, involved in doubt and disputation. It is unfortunate indeed, that in no branch of science whatever the imagination has more wantonly sported than in this; in no science have men appeared so desirous of deserting the only sure

sure guide, experience; in no instance has it been thought proper to resort so little to proof and observation, or to attribute so much to conjecture and theory.

Metaphysical subtleties, and hypotheses carried to a visionary extreme, have, therefore, greatly contributed to confuse this branch of knowledge; though when extricated from these, I apprehend full as much is known in this science as in any other, and perhaps more than in most. On this account I shall carefully avoid all those disputed points concerning identity and diversity, existence, infinity, &c. that have divided the learned from time to time. I consider them, in truth, as utterly foreign to my purpose, and as tending to establish no one useful principle. It will be unnecessary also to examine the origin of our ideas, or to enter into nice disquisitions concerning space, duration, &c. &c. as such inquiries are certainly more curious than useful.* I shall further avoid all fanciful theories respecting the nature of our perceptions. Some of them, I confess, are plausible, but I rather chuse to lay the ground work of my reasoning on actual experience; let those who so incline, extend at their leisure their researches further.

That scheme, which reduces human nature to the fewest principles, if these can be demonstrated adequate to every moral effect, is most satisfactory to the rational inquirer. The more of nature we discover, the more simple she appears in her operations: it is unphilosophical unnecessarily to multiply causes. It is evident, for instance, that there exists in men a relish for beauty, as well as for moral excellence,

cellence, and an antipathy to vice and deformity. But how are these affections generated? It is an indolent method of philosophizing to stop at whatever is not easily understood. Final causes and inherent instinct have saved the labour of many a painful investigation.

With respect to the actual existence of innate ideas or principles, the reader will perceive that I am not anxious to renew the controversy. Innate ideas, I believe, have been in general given up by philosophers since the time of Mr. Locke. A moral principle has, indeed, been contended for by some writers of the highest reputation, as being innate in man. It may be considered either as a sixth sense, as something inseparable from the soul or mind of man, or as a general instinctive result of his mental organization. I must observe, however, that the existence of such a principle has never yet been satisfactorily proved, though, on the contrary it is not easy to disprove it; I shall, therefore, as much as possible, avoid the controversy, and endeavour, as far as observation enables us, to account for the operations of our minds in the simplest and easiest manner, and to have as little recourse as possible to principles which are involved in doubt or obscurity.

The elementary part of this book will naturally divide into two branches. The first part will extend to the end of the eighth chapter, in which I shall endeavour to explain the instruments and the modes of action of the human mind. The second will extend from the ninth chapter to the thirteenth, in which the springs or incentives that produce

action in the mind, and influence its movements, will be examined.

The materials, upon which the human mind is principally to act, are the traces or vestiges left by external impressions on the five senses. Of these a simple effect on any one sense produces what is called a *simple idea*, the word *idea* signifying, an image or representation in the mind of an action, quality, or sensation; thus *white* and *sweet* are simple ideas.

An idea, compounded of several simple ideas, is called a *complex idea*, as *man*, *horse*, *tree*, &c. which are evidently compounds of a number of simple ideas of figure, colour, solidity, &c. and sometimes for distinction's sake, when many *complex ideas* are compounded in one, the disciples of Mr. Locke call it a *decomplex idea*, as *homicide*.

Impressions on the senses are often so entwined or associated together, that the idea of the one shall not be recollected without that of the other. This junction happens when two impressions are made on the senses at the same time; thus the *whiteness* and *roundness* of a globe may be associated; the form and the sound of a musical instrument; the name with the thing, so that on the sight of the thing or object we immediately recollect the name. Ideas may associate with impressions, if an impression is made on any of the senses, while an idea is predominant in the mind. Thus the sight of a particular place will often recal some interesting train of thought, that may have been entertained there. When I speak of ideas being associated, connected, combined, &c. I would be understood of the same thing, viz. the implexion or junction of ideas thus explained.

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The retention of ideas in the mind is called *memory*. The act of combining old ideas into new ones, *invention*, and frequently imagination or fancy. The act of examining and comparing them *judgment*. Under these heads I propose explaining the primary operations of the mind, and these will constitute the first part of the present inquiry.

The second part of this book will consist of an inquiry into the common springs of action in the mind. These I shall endeavour to prove to be ultimately the senses of *pleasure* and *pain*. *Love* is the idea of pleasure, combined with some other idea; *hatred* the idea of pain, combined in the same manner. *Desire* and *aversion* are active love and hatred *.

The third part, which extends from the thirteenth chapter to the conclusion of the work, will consist of the application of these principles to the investigation of some curious subjects, and to the theory of morals. This, as it is the most extensive part of the subject, is necessarily the most imperfect, and the chapters that constitute this part, are rather exhibited as confirmations of the preceding principles, than as a complete system.

* The *natural appetites* of man are,

1st. The common call of *nourishment* for the body, 2d. The desire of propagating the species.

The *natural pleasures* of man are,

1st. The satisfying of these appetites, 2d. The general pleasure resulting from the moderate and proper exercise of the organs or faculties.

CHAP. II.

OF PERCEPTION.

The Senses the great Source of Information.—Distinction between Sensation and Perception.—Senses correct each other.—Whether the same objects produce similar Perceptions in different Men.—Ideas.

THAT the mind is obliged to the senses for the great mass of its information, is now an established principle. The proofs of this doctrine I shall decline entering upon for reasons already assigned. I would only observe, First, That I do not see why we are furnished with senses by the author of nature, if not for this purpose. Secondly, The senses seem entirely adequate to all the information we are possessed of. Thirdly, Persons wanting any of the senses appear entirely destitute of the ideas of that sense. A gentleman, blind from infancy, assured me, he never remembered to have experienced in a dream any thing like what the sense of seeing is described to be. Nay, those who have all the senses complete, derive plainly their knowledge from the exercise of them. A child does not shrink from a candle till it has felt the painful sensation of burning, or is warned against it in terms expressing pain, of which it forms a judgment from pain already experienced.

A very proper distinction is made by Dr. Stuart, between sensation and perception. Sensation implies “ that change in the state of the mind which
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is produced by an impression upon the organ of sense; of which change we can suppose the mind to be conscious without any knowledge of external objects. Perception expresses that knowledge we obtain, by means of our sensations of the qualities of matter *."

† Sensations may be communicated from without; 1st. by actual contact with the object itself; 2dly, by the intervention of some medium: and it amounts to the same, whether we perceive the qualities of bodies by a communication with the bodies themselves, or by the effects which they uniformly produce on some medium which communicates with our senses. Thus, when we see a body *white*, we do not say that the light is perceived by our senses, but the whiteness of the body, or that property in the body which so disposes the rays of light

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* Outlines of Mor. Phil. p. 21, 22.

† The different senses by whose operation we discern the qualities of external objects, have been already stated to be five in number. Touching, tasting, smelling, hearing, and sight. They may perhaps all be resolved into that of feeling; yet the distinction is correct, as they are certainly different instruments of feeling or perception. In those of touching and taste an actual contact with the body, which is the object of the sense, is requisite. In the others the sensation is effected through the operation of some medium. Thus sight is in reality the effect of the rays of light upon our optic nerve; sound is a vibration of the air, which affects the organs of hearing; and smell depends upon the emanation of certain particles from a body, which act upon the organ of scent.

That some senses are more acute in certain animals than in others, is an obvious fact. The power of smelling in some of the canine species is beyond any thing that we are able to con-

as to afford us the perception or idea of *white* *. When, therefore, we speak of smells, tastes, colours, sounds, we mean that certain effects are uniformly wrought upon our senses in certain circumstances, and to the unknown causes we assign these names.

The information of the senses is the last resort of human reason; I mean their joint information, for it appears they correct each other. It has been already stated, that the judgments we form of material things are not so much the effect of an impression on any one sense as of those of seeing and feeling combined †. Simple impressions or perceptions are not to be defined, nor do they, from that agreement and analogy which exists between the senses of all mankind, require definition.

It is of no consequence whether the senses of different men perceive exactly alike, though it is probable there is not much difference in this respect. It is of no consequence, whether one man sees ob-

ceive. Cats and owls have undoubtedly a power of seeing with a much smaller portion of light than any human being. It is probable that in different men some senses may be more acute than others.

* There is undoubtedly something in objects which excites sensations, but the sensations themselves cannot exist without a subject on which to act. The disputes therefore of philosophers, whether smells are in the nose or in the person who smells them, &c. &c. are merely *de lana caprina*; and there must be a union of causes to produce such effect. Such disputes may serve to exercise the human faculties, but they undoubtedly make no addition to our stock of real knowledge.

† See Book 9. c. 37.

jects

jects larger than another, or whether the same composition affords to each precisely the same taste or smell. We communicate our ideas of sensations by the help of relation; we call a thing small when compared with another; we call the taste of a certain viand sweet, or a sound grave or deep, and we have nothing further to do to be clearly understood, than to mark the proportionate differences and relations.

It is to be remarked, that all objects that present themselves to our senses do not make such impressions as to leave ideas behind them. Many times the mind is too much engaged with one train of thoughts to admit another. An impression or sensation being perceived by the mind, the trace or vestige it leaves behind is called an *idea*.

Whether the mode of conveying perceptions from the senses to the understanding, is by a vibratory motion of the nerves * or by any other means, is of no consequence to the present inquiry. It is sufficient to say, that the senses are first affected by external objects, that these impressions leave behind them vestiges which are called ideas, and from the natural or voluntary combination of two or more of these, a new idea may be formed.

* Such is the theory of the ingenious, but visionary Hartley.

CHAP. III.

OF IDEAS.

Ideas of Sensation and Reflexion.—Simple and complex.—Modes and Substances.

ID E A S being the images of impressions, want their force and vivacity. 1st. Ideas of sensation are the mere representations of effects wrought on the senses. 2dly, We give names to the particular actions of our own minds, as perception, thinking, doubting, reasoning, and these Mr. Locke calls ideas of reflexion*.

It is probable many of our first ideas are complex, that is, the result of several sensations combined or united together. A child will hardly distinguish between the figure and colour; as in a glass globe, it will have the idea of the globe itself, before it will distinguish between the roundness and the brightness of which it is compounded; they are nevertheless as distinct ideas as sweetness and hardness, which may exist in the same substance, and one of them not be perceived as united with the other. "Though the hand feels softness and warmth in the same piece of wax, yet the simple ideas in the same subject are as perfectly distinct as those that come in by distinct senses." Simple ideas will be recollected in objects differing in every respect but that one, from those by which we originally re-

* Locke, B. 2. c. 2.

ceived

ceived them. Though a horse, for instance, may possess no obvious quality in common with a book, but that of external colour, as blackness, yet that quality will be recollected to be the same in both; and thus we learn that colour is not the necessary concomitant of figure, by finding the same colour united with different figures; and in the same manner, probably, we learn to disjoin all those simple ideas that enter by the same sense, as solidity and warmth, &c. &c.*

All our ideas of substances are complex, and are compounded of the various simple ideas jointly impressed, when they presented themselves to our senses. We define substances only by enumerating those simple ideas; and such definitions may sometimes produce an idea tolerably clear of the substance, in the mind of one who never immediately perceived the substance itself; provided he has separately received by his senses all the *simple ideas*, which are in the composition of the complex one of the substance defined †.

Words representing complex ideas do not always precisely excite the same idea in different persons. Some of the simple ideas may have made a

* The most enlarged understanding cannot frame one new simple idea; nor by any force destroy those that are there."

Locke.

† The word substance generally applied, means no more than the supposed, but unknown support of these qualities, which are capable of producing simple ideas in us. The ideas of particular substances, are composed from such combinations of simple ideas as are observed to exist together, and supposed to flow from its particular internal constitution. Locke, B. 2. c. 28.

stronger impression on one man than another, and some may have totally escaped him. The word *man* will, with a painter, call to mind several minute circumstances in the external appearance; with an anatomist the skeleton, nerves, &c. will hardly escape animadversion; with a metaphysician, the mind, or more properly the modes of acting, the powers and faculties will be recollected. In all complex ideas, however, which are the immediate objects of sense, and which are not decomplex, or composed of successive impressions, the more obvious qualities will serve to mark the idea, and identify it to every man; as the idea *horse*, *tree*, &c. can never be differently apprehended. It is otherwise with more abstract and remote terms; the word *virtue* may be very widely conceived of by different persons, as the customs of their countries, the course of their studies, or their turn of thinking, may determine; hence in all arguments, terms should be minutely defined.

All complex ideas are combinations of simple ideas associated together, as will be explained in the chapter of association.

Besides this division of ideas into simple and complex, metaphysicians have adopted others, which it may be of some use briefly to explain*. A principal division is into substances and modes, that is, modifications of matter or forms of existence.

Hence follows a division of modes into *simple* and *mixed modes*. Simple modes of *duration*, are whatever distinct ideas we have of any parts of it, as hours, days, &c. &c. Simple modes of *colour*,

* See Locke, B. 2.

are white, blue, &c. &c. Simple modes of *space* are any particular lengths of it, as an inch, a foot, &c. Simple modes of *motion*, are sliding, walking, &c. It would be useless to enter into any more particulars of this kind, as these distinctions are pointed out rather with a view to the works of others than to the present treatise. I would wish to observe, that the general terms *colour*, *space*, &c. do not furnish any *distinct* idea; we can have no clear idea, but of a particular colour, &c. as will be explained when I come to speak of words.

Mixed modes are defined by Mr. Locke to be "such combinations of simple ideas, as are not looked upon to be the characteristical marks of any real beings that have a steady existence; but scattered and independent ideas, put together by the mind, are thereby distinguished from the complex ideas of substances *," such are *hypocrisy*, *drunkenness*, &c. The ideas of mixed modes are acquired first from experience; as by seeing two men wrestle, we acquire the idea of *wrestling*. 2d. By putting together in the mind several successive actions, as a *lie*.

* Locke, B. 2. c. 22.

CHAP. IV.

OF ASSOCIATION.

Synchronous Associations.—Successive Associations.—A great Part of our Knowledge consists of the latter.—Common Sense.—Train of Ideas.—In what Manner the Train of Ideas is carried on.—Relations of Contiguity &c.—How these are formed in the Mind.—How the Train of Ideas is regulated.—Influence of the Will.

THE word association was, I believe, first used in this sense by Mr. Locke; the doctrine is notwithstanding very ancient. Plato and Aristotle in many of their writings, evidently allude to this connexion of ideas. Some of the Stoics remark its effects in speaking of custom, opinion, &c. and Antoninus is very clear upon the topic*. Hobbes has a whole chapter upon the train of ideas †, and makes considerable use of the doctrine through the whole of his work.

* Ποία αὖ πολλὰ καὶ φαίλαδες, ἰσχυρὴ σοὶ ἐστὶ ἡ διανοία. Βασιλεὺς γὰρ ὑπο ἰσὺν φαίλασιν ἡ ψυχὴ.—Anton. l. 5. c. 16.

† “In a discourse on our present civil war (says he) what could seem more impertinent than to ask, as one did, what was the value of a Roman penny? Yet to me the coherence was manifest enough. For the thought of the war introduced the thought of the delivering up the King to his enemies; the thought of that, brought the thought of the delivering up of Christ; and that again the thought of the thirty pence, which was the price of that treason: and thence easily followed that malicious question; and all this in a moment of time; for thought is quick.”—Leviathan, pt. i. c. 3.

I do not find that any one discovery has been made in the science of mind since the time of Hobbes.

Two

Two sensations happening at the same time will become united, and the ideas will be united of course; thus the ideas of the figure and colour of bodies, admitted by the eye, are united, and these may be united with another idea admitted by the touch. As the ideas of roundness and whiteness by the former, and solidity by the latter, are associated together in the complex idea of a stone. If music is heard, while we behold the instrument, the sound will be associated with the visible appearance, and the former will at any time recal the idea of the latter, when we do not see the instrument*. Names become associated with things, and things with actions†. Associations formed from impressions made at the same time, are called synchronous. But it is evident that impressions remain some moments
on

* "The names, smells, tastes, and tangible qualities of natural bodies, suggest their visible appearances to the *fancy*, and vice versa."—Hartley on Man. c. 1. s. 1. prop. 5.

† "It is remarkable, however, as being agreeable to the superior vividness of visible and audible ideas, that the suggestion of the visible appearance from the name, is the most ready of any."—Ibid.

"The transition from the words to the ideas, is generally much easier than from the ideas to the words. A person who is learning a strange language, will be able to understand a book in that language long before he can write or speak it. Even in one's native tongue, one can readily understand what is written or spoken in the best and properest terms, though he could not have used these terms for expressing the same ideas, &c. This proceeds from the influence of custom, &c. The ideas are more *familiar* to us than the words; they are often raised by their proper objects, or suggested by other words: and their *familiarity* makes them be suggested readily. That this is the true cause, is confirmed by observing that
where

on our senses, and die gradually away*; if another impression therefore is made while the former remains, they will be associated, and the one shall recal the other to remembrance: the association being weaker or stronger in proportion to the state of the idea or impression with respect to its vividness. An idea may in the same manner be associated with an impression or sensation, or two ideas may be associated together, and this kind of association from contiguity of time may be termed successive. Those complex ideas which are formed from synchronous impressions are more vivid and distinct, than those formed from successive ones.

Propositions founded upon synchronous impressions, are little else than complex ideas of sensation; as in the proposition "the dog barks," the idea of the thing is as much associated with the action as with any of its qualities: and here is no room for dissent, unless we could find that our senses had deceived us.

Propositions founded on successive impressions, are much more liable to deception; yet of these consists by far the more valuable portion of our knowledge. It is remarkable, how in forming these propositions, frequent experience leads us to drop the intermediate ideas, and connect the two extremes of the proposition, calling it self-evident,

where it does not take place, ideas are not suggested more readily than words are in ordinary cases. When the ideas expressed are such as we have been little accustomed to attend to, a discourse or composition is understood by us with difficulty, as well as when ideas are expressed by unusual words.—Gerard on Gen. pt. 2. f. 2. note.

* See Sir Isaac Newton's Optics, and b. ix. c. 41.

as if it was really the effect of synchronous impressions. "We may observe (says Mr. Locke *.) that the ideas we receive from sensation, are often in grown people altered by the judgment without our taking notice of it. Thus a globe of any uniform colour, as of gold or jet, being set before our eyes, the idea thereby imprinted, is of a flat circle variously shadowed. But being accustomed to perceive what kind of appearances convex bodies are wont to make in us; the judgment alters the appearances into their causes; and from that variety of shadow or colour, frames to itself the perception of a convex figure of one uniform colour."

A man who reads or hears with attention, takes little notice of the characters or sounds, but of the ideas that are excited in him by them. Thus we find the intermediate, associating ideas are dropped, and the more remote causes immediately connected with the effects. In the instance of the globe, the first complex idea presented, is that of a circle associated with certain shades of colour; on approaching and examining it by the touch, we find that this is really a convex figure and of a self colour, we therefore associate the ideas of the convexity and colour with the former idea of the circle so shadowed, and the one occurs not alone, but always accompanied with the other, and so immediately that we feel it as if it had been from synchronous impressions. It is unnecessary to multiply instances; it is obvious that the sight of blood never fails to

* B. 2. c. 9.

alarm the mind instantaneously, though no more productive of fear or horror from its natural properties than any other fluid. "Painters, statuaries, anatomists, architects, see at once what is intended by a draught, picture, &c *." Something like this occurs in moral propositions, as, "intemperance is productive of ill health." Here it is plain that common experience so frequently unites the consequence to the cause, that omitting all the intermediate steps necessary to form the conclusion, the mind is satisfied with the assertion, and calls it self-evident. This is what some authors (if I am not mistaken) mean by *common sense*; and indeed these conclusions are so generally right, that although it may be for the interests of virtue, occasionally to examine them by the principles of reasoning, men in most cases have very little occasion for any other appeal than to their common feelings, to determine on the justice or injustice of particular actions; ideas of justice being founded in the truth of things, and so confirmed by experience, that the conclusions are as ready at hand, and almost as clear as that "the sun shines;" "what is, is;" or any other of those maxims that are really self-evident.

On this principle of association depends the necessary succession of ideas in a train, of which any one may satisfy himself by attending to the operations of his own mind. Ideas are introduced by an agreement in some of the parts of which com-

* Hartley on Man, prop. 23.

plex ideas are composed. Shakespear, describing a merchant's fears, says,

“ My wind, cooling my broth,
“ Would blow me to an ague, when I thought
“ What harm a wind too great might do at sea.
“ I should not see the sandy hour-glass run,
“ But I should think of shallows and of flats;
“ And see my wealthy Arg’fie dock’d in sand.
“ Should I go to church,
“ And see the holy edifice of stone,
“ And not bethink me straight of dangerous rocks * ?

It is remarked, that the train of ideas almost always depends upon the relations of contiguity in time or place, cause and effect, resemblance or contrariety; all of which, it is obvious, depend on the principles of association already explained. It has been fully proved, that ideas are associated by contiguity of time, the former impression remaining vivid some moments after it was first made, and the other during that time occurring, they become united. That association which arises from unity of place is no other than recollection, the place making a part of the complex idea of any action. Cause and effect are associated by contiguity of time; for, as Mr. Locke observes, “ we get these ideas from our observation of the vicissitude of things, while we perceive some qualities or substances begin to exist, and that they receive their existence from the due application and operation of other beings *.” The relation of resemblance is

* Merchant of Venice, sc. 1. † Locke, B. ii. c. 26.

no other than recollection of that particular idea, in which the object present, and the object remembered, agree. When two ideas are formed, agreeing in any quality or qualities, they are said to be related; and the degrees of relation are as they agree in fewer or more qualities. Resemblance in one simple and very common quality, as black, round, &c. will seldom recal an idea, unless very recently or very strongly imprinted, the mind being confused with the multitude of objects possessing that quality.

The association of ideas with their contraries seems to arise, 1st, When the idea so remembered is only a negative idea, and derives its existence from its positive; thus cold is the want or decrease of heat; sickness is the want of health; poverty of riches; &c. 2d. When the ideas are connected in point of time *, as must be the case in a change from one state to another, such are the ideas *danger* and *safety*. 3d. Perhaps two things, which are opposite, being perceived at once, the mind is more forcibly struck by each of them, the ideas are consequently more vivid, and more liable to be recollected.

The train of ideas is often regulated by some *end* proposed to ourselves; for where we have an object in view, such ideas as are connected with it will of course be suggested. By these means we are frequently imposed on; a passion or an interest will lead on a train of arguments favourable to

* "Eye-witnesses generally relate in the order of time, without any express design of doing so."—Hartley on Man.

them, while we imagine we are acting with the utmost impartiality*.

‘The indirect influence of the will,’ says Dr. Stuart, ‘over the train of our thoughts, is very extensive. It is exerted chiefly in two ways:—1st, By an effort of attention we can check the spontaneous course of our ideas, and give efficacy to those associating principles which prevail in a studious and collected mind; 2d. By practice we can strengthen a particular associating principle to so great a degree, as to acquire a command over a particular class of our ideas.’

* ‘Should any one be surprised at this disposition in our nature to associate any ideas together for the future, which once presented themselves jointly, considering what great evils, and how much corruption of affections is owing to it, it may help to account for this part of our constitution, to consider, “that all our language, and much of our memory, depends upon it;” so that, were there no such associations made, we must lose the use of words, and a great part of our power of recalling past events, beside many other valuable powers and arts which depend upon them.”

Hutchinson on the Passions, s. i. p. 11.

CHAP. V.

MEMORY*.

*Ideas of Memory.—Distinguished from Ideas of Imagination.—
Judgment concerning Distance of Facts.—Memory in Young
and Old Persons.—Recollection.—Certainty,*

IT appears, that ideas of memory are distinguished from ideas of imagination; 1st, By being more vivid; 2dly, By the associated ideas of time, place, and other circumstances that accompany them. As ideas, by being often repeated, become more vivid, it is a common remark, that persons inclined to habits of falsehood, by often repeating the same story, are themselves at last imposed on by the vivacity of the idea, so as to mistake it for an idea of memory. Madmen are almost always deceived in this way. In dreams, the vividness of the new scene, and no associated ideas appearing by which to mark those ideas derived from memory, cause us to mistake it for a series of real impressions.

It seems probable, that we judge of the distance of facts recorded by the memory, 1st, From the idea growing fainter, yet retaining the principal

* • Memory is that faculty by which traces of sensations and ideas recur, or are recalled, in the same order and proportion, accurately or nearly, as they were once actually presented.—*Hartley on Man, Introduc.*

associated circumstances; 2dly, From enumerating ideas of facts, which we know, by the order of ideas, to have successively happened since that point of time in which the idea first occurred. The death of a friend, or any interesting event, often related, appears to have happened but yesterday, as we term it, on account of the vividness of the idea corresponding to the nature of a recent event*. Mistakes are here prevented in persons, who retain their senses, by the second means of judging, viz. by enumerating facts that have since occurred, &c.

Memory is weak in children; 1st, probably, because the organs are flaccid and weak; 2dly, For want of a number of ideas, which experience furnishes, and which afterwards strengthen the powers of association. Memory is slow and defective in old persons; 1st, Because, probably, a rigidity of fibre may render the organs of thought less active; 2dly, Because the passions are weaker, there is in reality less life, of course a sluggishness of mind will generally accompany that state. Impressions are easily made on the senses of children, but do not remain. On the contrary, it is difficult to make such impressions on older persons as to produce ideas, but when made they are lasting. Hence the necessity of inuring the mind to action and study through every stage of life, such persons frequently retaining their mental agility and powers longer than others.

Ideas are more easily recollected, 1st, By being vividly and distinctly impressed; 2dly, By being

* Hartley on Man, prop. 42.

strongly associated. These two causes will generally concur, for the more vivid an impression is, the longer it remains on the sense, and of course the more ideas it will be associated with. A sentiment, when quoted from a book or a poem by another author, as apposite to his subject, often makes a more distinct and vivid impression than in the original writer. The impression is more vivid, because we are apt to fancy that some peculiar excellence induced another author to quote it; it is more vivid too, because it is more distinct; it is better remembered, both for this reason, and because (like all distinct ideas) it becomes associated with time, place, and other circumstances, as well as with the ideas of him who quotes it*.

The following are the modes of memory pointed out by Mr. Locke, which may be of some use as definitions. 'When an idea recurs without the presence of the object, it is called *remembrance*; when sought after by the mind, and brought again in view, it is *recollection*; when held there long under attentive consideration, it is *contemplation*; when ideas float in the mind, without regard or reflexion, it is called *reverie*; when the ideas are taken notice of, and, as it were, registered in the

* 'We remember that best, which we understand most perfectly. What we understand, strikes us with its whole force: of what we understand imperfectly, it is only the part understood that makes any impression on us; of the rest we have no perception: even that part makes but a faint impression. It would acquire additional force from its connexion with the other parts, if the whole were understood.'

Ger. on Gen. part ii. f. 9.

memory,

memory, it is *attention* ; when the mind fixes its view on any one idea, and considers it on all sides, *study* *.

That ideas are commonly recollected in a train has been already noticed. It has, indeed, been disputed, whether we have any further power in recollection, than, 1st, Exciting a certain degree of activity in the mind, and awakening it to the different associations † ; and, 2dly, When two trains of ideas occur, directing the attention to one in preference to the other. The order of time, place, &c. have great influence in recollection.

In recollecting a company, we are obliged to have respect to the order of place, to the course of conversation, or some other of the common relations. Recollection in order of time happens from some part of two ideas becoming entangled with each other, as the mind, when waking, is seldom without some idea, so no one is perfectly gone before the introduction of another. Recollection from place happens by the transition which the mind makes from the first idea to the place, and from the place to the second idea ; it is the same in

* Locke, b. ii. c. 19.

† ' The mention of a person often makes us recollect, that there is some purpose for which we want to see him ; but sometimes, when we cannot call to mind what it particularly is, the sight of that person brings it quickly into our thoughts. In consequence of the superior force of sensations, which enables them to suggest conceptions by means of much weaker relations than ideas can, it often happens, that an object occurring to the senses gives a very quick and seemingly unaccountable turn to the course of the thoughts.'—*Gerard on Gen.* part ii. f. 3.

recollection from resemblance. Recollection from cause and effect is the same as recollection in order of time; only it is to be remarked, that we look upon every thing as being both a cause and effect of some other thing, though of what, or in what manner, we may be ignorant; and this is the result of experience.

An idea frequently recollected becomes associated with a number of other ideas in the different repetitions of it; it will therefore be more predominant, and more apt to be recalled on future occasions; and this constitutes the power of habit over our turn of thinking, which may be acquired from reading frequently the same book, or conversing much with the same person.

Distinct memory thus depending on association, the simple ideas are often found to remain, while the circumstances first connected with them are utterly lost. These the mind forming into new combinations, we call invention.

As memory is so much dependant on association, it is evident, that what influences the latter will have much effect in determining the peculiar excellence of any man's memory. Some are found to have a memory adapted to the remembrance of historical facts, some to poetry, &c. Ideas formerly received are so many hooks (if I may be allowed the expression) that fasten on those ideas which assimilate with them.

The distinctness, liveliness, and connected circumstances of ideas, leave almost no room for mistakes in judgment, as far as depends on the memory. Ideas of memory, by frequent repetition,
may

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may be retained equally perfect and vivid as when first imprinted; it follows, therefore, that when, from the clearness and vividness of the ideas, we feel that they have remained unconfused in the mind, our reasoning, as far as respects them, will fall nothing short of absolute certainty.

How far the memory is dependant on the corporeal organs, has been often disputed. Some striking instances, to prove a very close dependence, have been furnished by different authors. An Italian poet is related to have fallen dangerously ill, and when he recovered, to have forgotten the very letters of the alphabet. Pliny speaks of a person, who, by a dangerous fall, forgot his mother and friends. Messala Corvinus, by a disease, forgot his own name. Valerius Maximus relates, that a citizen of Athens, by a blow of a stone on the head, forgot all he knew of polite literature, though in other respects he retained his memory *. In the Memoirs of the Royal Academy, 1711, there is an account of a young man, who, in a fever, forgot every thing he knew; but afterwards learned very quickly; so, retaining his faculties, he lost his former ideas †.

We must, however, be cautious of giving too implicit credit to these relations. Authors, as well as all other men, are too fond of the marvellous. It is certain, that the soul or mind of man cannot act, unless the instruments with which it is to act

* Plin. Nat. Hist. l. vii. c. 24.

† See instances of extraordinary memory, Plin. Nat. Hist. l. vii. c. 24.

are in a proper state. The mind is, therefore, affected by the infirmities of the bodily frame; yet, in lunacy, and other mental complaints, medicine is found to have but a feeble effect. That a person, from a mere corporeal injury, can have any *one* subject eradicated from his memory, while he retains others, is not to be believed.

Great memory is seldom consistent with imagination. The mind, in that case, seems to be too much occupied with old ideas to be disposed to form new ones. I have heard a gentleman, of a remarkably strong memory, complain, that when he sat down to compose, he experienced great difficulty, from being incumbered with the thoughts, sentiments, and language of other authors.

CHAP. VI.

OF INVENTION.

Invention; what.—Ideas of Memory and Imagination.—Invention and Judgment.

THE mind may be equally employed in making true as false combinations of ideas; in forming a system, and connecting ideas by their natural relations, as in depicting Centaurs, and making witty allusions; in either of which cases it is said to *invent*. In the former there seems to be a greater mixture of judgment, and this kind of invention is subservient to real science. On the contrary, when the invention consists in drawing strong and lively pictures or representations, either false in themselves, or heightening by rhetoric real facts, it is called *imagination*; when it consists in wild and unexpected combinations, it is called *fancy* *.

From the two last chapters it appears, that invention is altogether dependant on the principle of association. When a person is possessed of a mind sufficiently active to be easily affected with the relations pointed out in the preceding chapters,

* "When ideas, and trains of ideas, occur, or are called up in a vivid manner, and without regard to the order of former actual impressions and perceptions, this is said to be done by the power of imagination or fancy."—*Hart, Introd.*

we say of him, that he has an inventive genius: a quick discernment of those relations between complex ideas, will lead him to combine them into new ones, or to new arrange the order of his thoughts, which will amount to nearly the same. In an active mind, the ideas will be more vivid, and such a mind will notice many relations that would escape ordinary persons. When a mind is more conversant, and more affected with the relation of cause and effect, such will constitute a genius for the sciences. A genius for the arts is more forcibly struck with the relation of resemblance.

Hence, first, it follows, that the memory must be strong to supply a genius for either arts or sciences with materials for new improvements; and, 2dly, The mind must be active, and easily affected by the several relations.

The distinction between ideas of memory and ideas of imagination has been already mentioned. Ideas of memory must necessarily be more lively than ideas of imagination commonly are at first. Ideas of imagination are only formed from the ideas of memory, so that at most the figure is but at second-hand, and must also be less perfect than what nature has actually presented to our senses. Yet, if we remember what was said respecting the frequent repetition of an idea, it will be found, that ideas of imagination may, by this means, become fully as vivid as ideas of memory, which is the case with persons addicted to falsehood, as has been already remarked. But I will even go beyond this, and assert, that a number of vivid ideas, being combined into one complex one, and each having
its

its dependant train of ideas, the complex, or rather *decomplex* idea, by frequent repetition, will produce a stronger sensation than any one of its constituent parts. Hence it is a self-evident fact, that the intellectual pleasures and pains, though deducible from the sensible ones, are in reality stronger and more vivid, as any person may satisfy himself who considers a little the nature of *avarice*, *ambition*, or *love*.

It has been customary to establish a radical distinction between invention and judgment, as if they were distinct powers of the mind, and not the same power differently employed; but the only two great distinctions that I perceive in the human mind are, memory and genius, which, it is certain, do not always meet in the same person. Perhaps the reason they are seldom found to exist together, in any considerable degree, may be a certain inertness in minds of the former cast, which enables them to retain ideas in the gross, but which disables them from separating, analyzing, or making new combinations. A very vivid mind is not only struck with an object as a whole, but every constituent part is observed, and makes, if I may so express it, a separate impression; these parts are, therefore, liable to become separately associated with parts of other complex images, and the same vividness and activity of mind will produce naturally these frequent associations.

C H A P. VII.

OF JUDGMENT.

Judgment ; what.—Assent.—Probability.

WHEN the mind examines and compares objects or ideas, recalling in a series, and turning them over, so as to distinguish their natures, qualities, or relations, it is said to judge. To the act itself, or the power of performing it, we give the name judgment, and often the conclusion or inference is called a judgment.

Ideas are objects of the judgment ; first, in distinguishing one idea from another : this act of the mind has given rise to the technical terms used by logicians, *identity* and *diversity*. Mr. Locke calls this the first act of the mind, which, he observes, “ it does without any pains or deduction, by its natural power of perception and distinction.” 2dly, Ideas are objects of the judgment, in perceiving the relation which one bears to another, or the particulars in which they agree one with another. Thus, by the first, we observe, that blue is not purple ; and yet, by the second, we perceive, that purple approaches nearer the colour blue than yellow does. Or, to give a plainer instance—We perceive by the first act of judgment, that two is a different number from four ; and, by the second, that they have this property in common, that they are both even numbers.

Mr.

Mr. Locke observes, that truth and falsehood belong properly only to propositions *. Truth is, first, a conformity of the idea with the name; in other words, that in the minds of different persons the same name shall suggest the same idea. 2ndly, A conformity of the idea with some real existence. 3dly. A conformity of one idea with another.

The cause that a person affirms the truth of the proposition, twice two is four, is the entire coincidence of the visible and tangible idea of twice two with that of four, as impressed upon the mind by different objects. We see every where that *twice two* and *four* are only different names for the same impression. Where the numbers are so large, that we are not able to form any distinct visible ideas of them, as when we say, twelve times twelve is equal to one hundred and forty-four, a coincidence of the words arising from some method of reckoning, and resembling the coincidence of words, which attends the coincidence of ideas in the simpler numerical propositions, is the foundation of our rational assent; for we often do, and might always verify the simplest numerical propositions by reckoning up the numbers †.

Those judgments, which relate to determining the probability of future events, appear to be little more than accurately remembering, and selecting such principles as relate to the matter in contemplation. We can guess at the future only from the past. As when certain appearances happen, we remember, that the same appearances were formerly

* B. ii. c. 32.

† Hartley on Man, Prop. 38.

attended with certain consequences; the whole event is therefore presented to our minds, though not yet completed. The great difficulty is, to recollect accurately in what particular circumstances the present matter agrees with the past, and the degree of probability will be in an exact proportion to the circumstances in which they agree.

Thus we see memory furnishes the materials for the judgment; the conclusions drawn partake much of the nature of invention. In this the two faculties in a manner meet; and for this reason I conclude they are radically the same, only differently exerted. Reasoning is a chain of judgments founded one upon another. It is the arithmetic of words.

CHAP. VIII.

OF WORDS.

*Abstract and general Terms.—Uses and Abuses of Words.—
Thinking in Language.*

WORDS were adopted as the signs of ideas, which are images of things; they are a sort of coin current among men to transfer their thoughts to one another*. Words serve likewise to represent collections of ideas, as is the case in general terms.

On examining the principles of language, it appears, that the first words of every language relate immediately to things, their properties or actions. Men in a very rude state of society, have little use for abstract or general reasoning. All our adverbs, conjunctions, and prepositions, were originally verbs or † substantives.

To number would be extremely difficult without words: they serve to distinguish numbers, of which

* Words, in all men's mouths (that speak with any meaning) stand for the ideas which those that use them have, and which they would express by them. Thus a child that takes notice of nothing more in the metal he hears called gold, than the yellow colour, calls the same colour in a peacock's tail gold; another, that has better observed, adds to shining yellow, great weight; and then the sound gold stands, when he uses it, for a complex idea of a shining yellow, and very weighty substance.—Locke, b. iii. c. 2.

† See Mr. Horne Tooke's *Epea Pteroenta*; and *Essays Historical and Moral*.

we could have no distinct visible or tangible ideas. The nicest observer cannot have a distinct idea of ninety-nine, and another of an hundred, but by the words.

When we observe any quality, or set of qualities, that are connected with several different objects, we constitute thence an abstract word, such are *roundness, whiteness, human nature, &c.*

General terms are formed, by observing that there are some qualities in which certain things agree, though differing in others; we rank, therefore, all the objects so agreeing under a general head, or class them. These general terms do not excite any idea unless a particular one. Thus, if by the word *man* any idea is excited, it must be that of a particular man. The word *animal* is still more general, and if any distinct idea accompanies it, it is only that of a particular animal. Yet in this case there is no danger of confusion, if the general term is well understood, that is, if the particular qualities to which it is meant to refer are defined, and distinctly pointed out, then any man or any animal will serve completely to represent the whole class in those agreeing qualities, which the general term serves to express*. It is manifest this is a refinement of human invention to prevent the inconvenience of constantly referring to proper names, which would be almost as laborious as the contrivance of Swift's philosophers, to converse without

* In the whole business of genera and species, the genus, or more comprehensive, is but a partial conception of what is in the species, and the species of what is to be found in each individual.—See Locke, b. iii. c. 6.

words, by bringing the thing spoken of within sight of the parties.

The general terms representing *mixed modes*, such as *parricide*, *virtue*, &c. have only to be defined in the same manner, by pointing out the actions or qualities they are designed to represent, and there will be no danger of confusion or mistake.

Words representing complex ideas, which are objects of our senses, are defined by enumerating the simple ideas of which they are compounded.

Words representing simple ideas cannot properly be defined, for it is impossible to analyze the idea *white*, *sweet*, &c.

It is unnecessary to say any thing of the nature and use of those words called particles. Such a disquisition would be better adapted to a grammatical treatise, than to the present work.

Words may pervert our reasoning, either through passion or ignorance. As words, by being connected with objects, become in some measure capable of exciting pleasure and pain, so they may contribute to prejudice us for or against an object, when frequently united with it, as is evident in the use of the epithets *good*, *fine*, *elegant*, *frightful*, *bad*, &c. *

Whatever

* "It ought to be remarked, that the words and phrases of the parents, governors, superiors, and attendants, have so great an influence over children, when they first come to the use of language, as instantly to generate an implicit belief, a strong desire, or high degree of pleasure. They have no suspicions, jealousies, memories, or expectations of being deceived or disappointed; and therefore a set of words expressing pleasures of any kind, which they have experienced, put together in almost

Whatever disputes or misconceptions arise from ignorance of words, they generally happen in the names of *mixed modes*, or abstract general terms; for in the use of those words, which only represent complex ideas of sensation, there can scarcely be any mistake. The mistakes alluded to usually happen, 1st. From an idea being omitted, which ought to have been comprehended in that definition of a general term, which every man makes in his own mind. As in *chance-medley*, *man-slaughter*, *murder*, the *principal* idea is the same, yet the respective words suggest an idea materially different. 2ndly. From ideas being admitted, which ought not to be comprehended in the general term. 3dly, From an obscure or confused view of the meaning. 4thly. Disputes often arise, because a man may have a part of the ideas, which are comprehended under the general word, more strongly associated with his other ideas than the rest; of course he will have a partial view, and his reasoning will be biased by a kind of prejudice.

The first end of language is to make known our thoughts to others, in which we fail, 1st, When we use words without clear and distinct meanings; 2dly, When we apply received names to ideas, to which the common use of language does not apply them; 3dly, When we apply them unsteadily. The second end of language is to make known our

any form, will raise up in them a pleasurable state, and opposite words a painful one. Whence it is easy to see, that the fine language expressing praise, and the harsh one expressing dispraise, must instantly put them into a state of hope and joy, fear and sorrow respectively."—Hartley, Prop. 47.

thoughts

thoughts with as much ease and quickness as possible, and this men fail in when they want either names for complex ideas, or abstract and general terms. The third end of language is to convey the knowledge of things, and this cannot be done, but when the ideas agree with the reality of things*.

Other abuses of language, not noted above, are, 1st, Affected obscurity; 2nd, Taking words for things, as *abhorrence* of a *vacuum*, *substantial forms*, &c. to which I may add, taking *memory*, *judgment*, *imagination*, for distinct powers, and almost for distinct beings, instead of what they really are, only different modes of the mind's acting; 3dly, Figurative language.

The frequent use of abstract and general terms makes us think in language more than we otherwise should do; yet it is seldom that a chain of thought is carried on in a regular chain of words, as if we were explaining our thoughts to another, unless indeed when we con over a speech or any transaction where language is immediately concerned.

* See Locke, b. iii. c. 9.

CHAP. IX*.

OF PLEASURE AND PAIN.

Pleasure in consequence of Action.—By Association.—By Passion.—Utility.—Surprize.—Variety.—Regularity.—Imagination.

“**T**O excite us to the actions of thinking and motion (says Mr. Locke) the author of nature has joined to several thoughts and sensations a perception of delight; without this we should have no reason to prefer one thought or action to another, motion to rest; in which state man, however furnished with the faculties of understanding, &c. would be a very idle inactive creature, and pass his time only in a lethargic dream. Pain has the same effect (continues he) to set us on work that pleasure has; since we are as ready to avoid that as to pursue this.”

It is evident that pain and pleasure are relative terms, expressive of an alteration in the state of the person, bodily or mental. 1st. Some degree of pleasure or pain attends almost every impression on the five senses. 2dly. Relief from an uneasy situation is pleasure; thus, the wants consequent on our natural appetites are painful, and to satisfy them pleasant †. 3dly. The recollection of the ideas of those

* At this chapter the second part of this book commences, or that which treats of the active powers of man.

† The appetites, which are the springs of the passions, are, hunger, thirst, and the desire of procreation. The bodily affections

those things which are hurtful to the body, or ideas associated with them, is productive of trouble to the mind, and the contrary *, as will be amply proved in the progress of this volume.

So far is evident from experience. To ascertain the nature and cause of painful and pleasurable sensations is an inquiry of some difficulty. Anatomists and physiologists are, I apprehend, very generally agreed in one point; it will therefore be sufficient to subjoin the opinion of one of the most eminent, especially as the subject has been in part investigated on a former occasion †. ‘All I shall assume (says Dr. Monro) is what is founded on experiments, that sensation and motion do depend upon the nerves; that sensations are pleasant as long as the nerves are only *gently* affected, without any *violence* offered to them; but as soon as any force goes beyond this, and threatens a solution of union, it creates that uneasy sensation, pain.’ ‡

If we examine the whole of human life, we shall find almost the whole of positive pleasure to consist in action of some kind. Sleep will hardly come under the denomination of positive pleasure. It is desired, because it produces a relief from weariness, and is a state to which our bodies naturally tend

fections productive of pain and pleasure, and which are connected with the sense of feeling, are, sickness and weariness, and to these we may oppose the feeling of health and vigour, and the sensation of life, or the pleasure attending the moderate action of our senses.

* The expression of pain in the countenance is much the same, whether *bodily* or *mental*, only differing in the degree.

† See book ix. c. 36.

‡ Cheselden's Anatomy, chap. Nerves,

when fatigued; otherwise it is a state of insensibility, and it would be an abuse of language to call it pleasure. Some impressions are primarily grateful* and others disagreeable. That the painful and disagreeable are such by an intense degree of agitation, which strains and prejudices the organs of sense, is probable. It is also probable, that the agreeable follow the general law of our nature, and are pleasing on account of the gentle yet lively action or agitation excited in us. There will remain little doubt of the truth of this doctrine, if we consider that light and heat in a moderate degree are productive of pleasure, and in greater quantities hurt by their intenseness; that many acids, &c. which, when diluted, are agreeable to the taste, are highly painful when applied pure and unmixed*. In fine, absolute rest is the death of sense. Motion is the very characteristic of animal life; and most of our intellectual as well as sensible pleasures seem to depend on a moderate increase of action. Recalling an old idea, which is connected with a train of other ideas, is manifestly pleasing; and this appears to result from the gentle agitation imparted to the organs of thought. "The music was like the memory of joys that are past, mournful, but pleasant, to the soul." The pleasures of the imitative arts, of figurative language, of the sublime, the

* "There is no one, of ever so little understanding in what belongs to a human constitution, who knows not, that, without action, motion, or employment, the body languishes; and is oppressed, &c." "In the same manner the sensible and living part, the soul or mind, wanting its proper and natural exercise, is burthened and diseased," &c.

**Shaftesbury Enq. Con. Virtue*, b. ii. p. ii. f. 1.

beautiful,

beautiful, and still more, the pleasures of variety, will meet an easy solution on this principle *.

Of pains, some are positive, as really affecting the body †, others only affecting the mind by being connected with painful ideas; and further, pain is generally consequent on the absence, or deprivation of pleasure; that is, our expectations are disappointed, and we are robbed of the pleasure of hope, for we are ever in pursuit of pleasure; but the pain is always greater in proportion as the expectation was probable. Thus, there are many sounds, which, though very dissonant, scarcely give us pain; yet to a good ear the smallest dissonance in music is offensive. The same may be observed in painting, architecture, &c.

Our ideas flowing naturally in a train, whatever is introduced forcibly, and bearing not an immediate connection, pains the mind, because it distracts it with the variety of ideas, which are crowded together by the collateral circumstances introduced by it, as well as those depending on the former train of thought.

* This is to be understood, however, as nothing more than an attempt to account for the nature of pleasure and pain; and, I own, it appears to me the most rational I have seen. The establishment or rejection of this doctrine will not affect the truth of my general principles; and I can start fairly with this self-evident maxim, that pleasure and pain are the effects of certain impressions on all our senses, and that the cravings of the appetites are painful, and the gratification of them administers pleasure.

† “ Since the pains of feeling are far more numerous and violent than those of all our other senses put together, the greatest part of our intellectual pains are deducible from them.
—*Hartley on Man*, prop. 13.

An impression, which was painful, will leave a trace or idea of pain behind it, and a pleasurable impression an agreeable idea; these, it is plain, may be excited by any of the associated circumstances. But the strongest relation is that of causation. What we conceive to be the cause of painful or pleasurable sensations will be intimately combined with those ideas; and hence we always love or hate most vehemently what we conceive to produce pleasure or pain. But as the principle of association is not confined to the relation of cause and effect alone, any other circumstance associated by contiguity of time or place, or even by resemblance, will partake of the passion. It is well known that the very word *physic* conveys a disagreeable idea to children, who have been compelled to take nauseous draughts, and they can scarcely endure the person of the apothecary. The mention of particular medicines will sometimes excite vomiting in very delicate and irritable habits. Some medicines, palatable in themselves, from the idea of their painful effects, we nauseate.

The sensible pleasures are greater in number than the sensible pains. Of this, waving any abstract reasoning, such as the love of life, and the pleasures of habit, any man may be convinced, who will be at the trouble of enumerating them. Now our intellectual pleasures and pains are combinations of the sensible, and of course our pleasures will be more numerous than our pains. Ideas seem to have a similar effect on the mind to what some applications are said to have on the body, which are sedatives when applied in large quantities, and stimulants

mulants in small. "The sight of tortures chills the whole soul, and produces almost a total stagnation of thought *;" but relations of tortures have never any such effect, and men seem to find them agreeable, by the avidity with which they listen to them. The truth is, a very violent mental agitation is required to produce pain, and every moderate agitation will produce pleasure: a proof that the intellectual pleasures must be very numerous, and the intellectual pains very few. A description of a storm or battle, which is really composed of painful or disagreeable ideas, will excite in very few a degree of agitation which arises to pain, and most people experience an actual pleasure from these descriptions. The very deformities of nature, a rugged and frightful hill, or a storm of lightning, give us pleasure, when exactly copied; and we read with pleasure even of ill actions, and see the cruelties of tyrants represented on the theatre with a kind of solemn delight †. This can only result, 1st, From the mental agitation, which these trains of thought produce. 2dly, From some agreeable ideas, which may be connected with the train of thought; for the mind is ever ready to turn and embrace pleasing associations, and seldom fond of

* Gerard on Genius, part ii. f. 4.

† At the subsiding of grief there is a certain melancholy pleasure. A distant view of the misfortunes of others affords a similar sensation; but they produce pain if they touch us nearly; and some hearts are so susceptible, that they are moved much easier than others. On the imagination being excited to action, we feel a most agreeable sensation; and it is a common maxim among authors, to leave something to the imagination.

purfuing a difagreeable train. 3dly, Variety is generally connected with rude nature, and imperfect characters.

The pleasure refulting from narratives of apparitions, enchantments, &c. may be accounted for on the fame principles; and from the pleasure attendant on them results the eafy belief which men afford to fuch fancies.

The pleasure of *utility* results from the ideas of pleasure that are associated with the ends of any work or undertaking. Hence thefe pleafurable ideas become associated with the employment itfelf. Though in fome inftances this effect may be counteracted *, the general principle holds neverthelefs true.

Pleasure

* “ A prifon is certainly more ufeful to the public than a palace; and the perfon who founds the one is generally directed by a much jufter fpirit of patriotifm than he who builds the other. But the immediate effects of a prifon, the confinement of the wretches fhut up in it, are difagreeable, and the imagination either does not take time to trace out the remote ones, or fees them at too great a diftance to be much affected by them.”—*Smith's Theor. Mor. Sent.* part i. f. 3. c. 3.

On the contrary, we may add, the pleasure, the gaiety, the greatness of thofe who inhabit the palace, naturally affect the mind with pleafing fentiments.

“ Trophies of the inftruments of mufic or of agriculture, imitated in painting or ftucco, make a common and an agreeable ornament of our halls and dining rooms. A trophy of the fame kind, compofed of the inftruments of furgery, of diffecting and amputation knives, &c. would be abfurd and fhocking. Inftruments of furgery, however, are always more finely polished, and generally more adapted to the purpofes for which they are intended, than inftruments of agriculture. The remote effects of them too, the health of the patient, is agreeable; yet

Pleasure may result from *surprise* on several accounts. The agitation which a moderate surprise occasions is agreeable; but the surprise which is united with the satisfaction of finding ourselves safe, after fancying we were in danger, is still more exquisite; and, perhaps, the most exquisite of all is, when we find occasion for self-commendation, as in solving a problem, &c.

The pleasure of *variety* seems to be the effect chiefly of the moderate, and yet lively agitation, which several trains of thought induce.

Though it appears from all that has been said, that gentle agitation is in general productive of pleasure, yet the mind has likewise a natural love of ease, and will not bear much fatigue; a little exertion soon tires it; for this reason, regularity is pleasing, and the contrary. We readily embrace a regular figure; the train of thoughts flow naturally to the different parts; we comprehend it; our mind is satisfied with it. We pursue, with a kind of easy emotion, a regular series; and hence it is, that men have been so fond of reasoning from universal axioms. The irregular pleases in the works of nature from custom, and the ideas connected with them. Nevertheless, where the end is pleasure, we may lay it down as an universal rule, that

yet as the immediate effect of them is pain and suffering, the sight of them always displeases."—*Ib.*

"Instruments of war are agreeable, though their immediate effect may seem to be, in the same manner, pain and suffering; but then it is the pain and suffering of our enemies, &c. With regard to us, they are immediately connected with the agreeable ideas of courage, victory, and honour."—*Ib.*

an object ought to possess some degree of variety, without entirely departing from that uniformity we love.

The pleasures of the imagination I have asserted to be much more numerous than the pleasures of sense; and these result, first, from whatever of the beautiful is possessed naturally by the objects described. 2dly, From the associations of pleasure originally deduced from the senses with other ideas.

C H A P. X.

OF LOVE AND HATRED.

Definition of Love.—Origin of the Social Passion.—Dislike and Hatred.—Desire and Aversion.

LOVE is the idea of pleasure associated with another idea. Some of the first impressions of pleasure an infant receives are by the gratification of its appetites. Its first emotions of love are, therefore, towards the being that supplies it with food, &c.; and it is observable, infants never fail in this love. The idea of pleasure is in reality first united with the food itself, and of course transferred to it, and thence to the object by whom it is supplied. All our wants are satisfied (particularly in our tender years) by means of our own species; hence the most agreeable ideas are united with them, and so often repeated, that in time the love of mankind becomes, in a manner, a necessary part of ourselves; and from this source may proceed the social affections.

Dislike and hatred are the opposites to love, and result from the idea of pain combined with another idea. A child shall have no dislike to a certain medicine, till after it has produced nausea, or some painful sensation, and thenceforward he will scarcely hear it named without expressing his aversion.*.

The

* The idea of pleasure being annexed to a thing, constitutes it, as we say, good. The idea of pain (either immediate or related)

The passions have been analyzed, and thus reduced to *love* and *hatred* by some of the oldest writers on the subject now extant. It is evident, that *desire* and *aversion* are the same passions made active. Inanimate things may be the objects of love or dislike. "The house which we have long lived in, the tree whose verdure and shade we have long enjoyed, are looked upon with a sort of respect †." The Dryads and Lares, a sort of genii of trees and houses, were probably first suggested by this kind of affection.

Desire or the sensation of want, may be either sensual or imaginary; it may be fixed on the pleasure of gratifying an appetite, or on the delight accruing to the eyes or ears from the perception of beauty. When instruction, education, or prejudice of any kind, raise a desire or aversion towards an object, it must be founded on an opinion of some quality, for the perception of which we have the proper senses. Thus, if beauty is desired by one, who has not the sense of sight, the desire must be raised by some apprehended regularity of figure, sweetness of voice, smoothness, or softness, or some other quality perceptible by the other senses (without relating to the ideas of colour ‡) or from the commendation of others.

lated) evil. "These (as Mr. Locke observes) are the hinges on which the passions turn." See Locke, b. ii. c. 20.

† Smith's Theory Mor. Sent. part ii. f. 3. c. 1.

‡ Hutcheson.

CHAP. XI.

OF BEAUTY.

Of Beauty in general.—Original.—From Association.—Nature and Art.

WE may say in general of beauty, that it is some quality in objects capable of exciting unmixed ideas of pleasure, independent of the gratification of any of the animal appetites. This definition does not differ much from that of Plato, “Τὸ δι’ ὀφθαλμοῦ καὶ ἀκοῆς ἡδύ *.” Perhaps we give this pre-eminence to the pleasures not depending on appetite, as they are the most innocent, and least liable to disgust and satiety †.

The principal distinction between the pleasure afforded by sublime objects, and that by those which we term beautiful, seems to be, that the latter is pure unmixed pleasure from the gentle agitation, whereas the former borders upon pain (arising from some compound of the passion of fear) and is often not unmixed with actual pain, and always requires a greater exertion, and produces a more violent agitation of the organs of sense.

* “The pleasant to the senses of sight and hearing.”—Plato, *Hippias major*.

† *Ib.* Beauty is never properly applied to the sense of tasting, as it seems too coarse an enjoyment to be reckoned among the rational ones.

The pleasure afforded by risible objects * is not that tranquil pleasure which arises from the contemplation of beauty, neither is it pure or unmixed pleasure. Contempt, or some painful passion, is generally in some degree compounded with the risible idea.

The primary constituents of beauty seem all of them to be such as promote gentle agitation, and thus increase our sense of life. Such are, 1st, Lively colours, where they are not so strong, or the application so continued, as to produce pain †. The young man couched by Cheselden thought scarlet the most beautiful colour, and of others the gayest gave him most pleasure. The first time he saw *black* it gave him great uneasiness ‡. 2dly, Variety and contrasts of colours, where the transition is lively,

* Risibility is often productive of pleasure, as are some other affections which have no relation to what is called beautiful. Beauty seems most properly applied to a pleasing idea excited by some external object; but most frequently our ideas of beauty arise from associations, as the sense of propriety, ease, &c. &c.

† "It is evident that gay colours, of all kinds, are a principal source of pleasure to young children; and they seem to strike them more particularly, when mixed together in various ways."—Hartley on M. Prop. 22.

"In adults the pleasures of colours are very languid in comparison of their present aggregates of pleasure formed by association.—Ibid.

Green, the middle colour of the seven primary ones, is most grateful.

‡ Cheselden's *Anatomy*, p. 301. The boy couched by Cheselden was most pleased with *red*, perhaps, because it was the completest exertion of his newly acquired faculty. He dreaded *black*, probably, because it restored him to his former state, and was in fact a partial negation of sense.

*

without

without being too abrupt. Females of taste make much use of this principle in the choice of their ornaments of dress. 3dly, Certain sounds and combinations of them, analogous to those of colour just mentioned. 4thly, Flowing easy motion, without that violence which gives a double sensation of pain, viz. besides the harsh effect to our senses, an associated pain, by putting ourselves in the place of the object. 5thly, The agitation which a waterfall, a varied prospect, or an high ascent, produces, may be a source of that kind of pleasure we ascribe to beauty, even independent of the associated ideas. Hence it follows, that figures, which possess variety without any thing harsh or abrupt, the waving line, running water, and many of those constituents of beauty remarked by painters, are naturally and primarily such. These when so disposed as not to contradict any attachment established by custom, and still more when they coincide with it, as when nature is imitated in a fine landscape, or described in a poem, never fail to give pleasure; and hence it appears, that authors have mistaken who have described that which is most fit and regular as the most beautiful. Admitting, in the instance adduced by Plato *, that the wooden spoon might be most useful and proper; yet if even the value is set aside, I apprehend the golden one would be allowed to possess the most intrinsic beauty.

The associations that arise originally from the pleasures of sense may become so distant, that we lose sight of their origin; and to an object in this

* Hippias Maj.

ease conveying pleasure, men universally assign the epithet beautiful. Though it is probable, that most frequently some of the primary constituents of beauty will be compounded with it, and of this mixed nature are most of the objects we denominate beautiful, as a fine house, a landscape, a running horse, &c. On this account it is worth observing, we often find a whole to possess beauty, which by no means resides in the constituent parts *. The simple constituents of beauty have but little influence when put in competition with the desire of gratifying the appetites, or the fear of pain; to illustrate this, I shall only mention a universal and common prejudice. There is nothing really deformed in serpents; on the contrary, many of the acknowledged constituents of beauty, such as lively colours, variety, &c. are found in them; yet from a knowledge of their noxious properties we cannot by any means bring ourselves to view them with that pleasure which beautiful objects ought to inspire. An object which is beautiful will impart a virtue to every thing connected with it. Things preposterous and deformed in themselves are reconciled to us when worn by a beautiful person; and hence fashion derives its extensive influence. On the contrary, what is worn by rustics is lessened in our estimation by the awkwardness of the wearer. Men admire the very defects of their mistresses, and often judge of beauty by their peculiarities.

* *Hippias Maj. ad. fin.*" *Amatorem*

" Amorem quod amicæ

" Turpia decipiunt cœcum vitia aut etiam ipsa hæc

" Delectant ; veluti Balbinum polypus Hagnæ *."

Hence we may in a great measure account for both the uniformity and diversity of taste prevalent among mankind. There are some objects and qualities, which interest and are pleasing to every man ; others, with men differently circumstanced, receive a colour from other ideas, with which they may be connected. The human form is the most pleasing of all forms to every man, because from society he has derived all his choicest pleasures ; but whether white or black is to be preferred, whether an aquiline or a flat nose, will, perhaps, depend on early associations to determine.

The influence of association over our sense of beauty is further obvious in this, that scarcely any man exists, who does not annex to particular sets of features good and bad moral ideas ; and these will probably be drawn from particular persons. I knew a celebrated painter, whose best historical figures all bore some resemblance to himself ; and others have been known, who constantly copied their own wives as the perfection of beauty.

Rural beauties are so compounded of the primary constituents of beauty, united with so many things that gratify our appetites and senses, together with many complex pleasures, such as sports and pas-

* The dress of a judge or a clergyman, even when seen on the stage, is accounted elegant and respectable, and suggests correspondent ideas.

times, the amorous pleasures, &c. that it is no wonder these, with the encomiums of others, which have always an influence on imitative animals, should make them the almost unceasing theme of poets. Of the beauties of art I shall treat in another chapter.

CHAP. XII.

OF CUSTOM.

Pain from Custom.—Pleasure.—Admiration.

TWO observations naturally occur, when we contemplate the force of custom : 1st. That when we have been long used to see two things together, we do not with perfect pleasure endure to behold them separate. This is, in truth, a species of disappointment. The idea appears incomplete ; there is a want, and a painful sense of want. Thus a cow with but one horn, or a dog with one ear, is a disagreeable object, though, doubtless, if they had been created with but one, two would have been accounted a deformity.

2dly. It is commonly remarked, that custom will make us love almost any thing, and will reconcile us to almost any condition. The force of custom here seems to depend entirely on the principle of association. We have already seen that pleasures are more abundant than pains. There is, therefore, scarcely any state in life, which will not be productive of many agreeable ideas ; these ideas become connected with the objects and actions which have occurred, while they have remained impressed upon the mind ; the idea, therefore, that imparted the pleasure, and the other idea, will become blended together ; nay, the sense of pleasure will be transferred from the former to the latter,

latter, so that it may recur united with a sense of pleasure, even when the object that originally imparted the pleasure is forgotten. Thus it is not at all uncommon to hear persons speak in rapturous terms of their past situation, when it is impossible for them to recount the reasons why it was so agreeable ; or, if they were to attempt to recount them, they would probably not assign the true causes. Actions and things in themselves indifferent thus borrow pleasures from others, and by this means attach us to them, as we have seen that fashions, without any one original principle of beauty, nay, even deformed in themselves, obtain respect and admiration from the beauty of the wearer.

It is thus that card playing, and some other habitual vices, not in themselves pleasant, acquire an empire over us. The desire of imitating others has, we will suppose, been our first motive for engaging in them ; they have been united in the course of our pursuing them with the pleasures of society, the occasional gratification of avarice, the pleasure of surprise, &c. and thus afterwards appear as pleasant themselves from their borrowed lustre.

Whether the love of life itself is an innate principle has been disputed ; for though infants fear pain, yet they have no apprehension of death, till reason has so far made a progress, as to inform them that it is connected with pain, and life with happiness. The love of life is generated from the sense of pleasure resulting from the goods we possess in it ; and this affords no inconsiderable proof that the good in the world overbalances the evil. So strongly, indeed,

deed, are the ideas of life and happiness associated, that most men would rather live miserable, than not live at all: thus again we see that an associated affection may overcome and counteract the natural affections, and even those that gave it birth.

It will be unnecessary to add any more in this place on this subject, or to endeavour to prove more at large the influence of custom. To an attentive reader, many facts throughout the remainder of this work will occur to confirm it, and almost all that has been said of a sense of beauty derived from association will apply likewise to moral beauty *. It is observable, that every nation and every age has a fashion in thinking as well as in dress; and the whole cast of thinking will be more uniform than men usually suppose. The sports of nations partake of the nature of their government, and their political prejudices and interests. Gladiators and mock battles were the favourite amusements of the warlike Romans.

Men love what is uncommon at first, because what produces mental agitation produces pleasure;

* "In the reign of Charles II. a degree of licentiousness was deemed the characteristic of a liberal education. It was connected, according to the notions of those times, with generosity, sincerity, magnanimity, loyalty, and proved that the person who acted in this manner, was a gentleman, and not a puritan."—Smith's Th. M. S. pt. 6. f. 2.

In the same manner as you are induced to love and imitate whatever is connected with a pleasurable or beautiful object, you will endeavour to avoid what is connected with pain or deformity. Hence men often act in extremes. Lord Bolingbroke asserted, that what first gave him a distaste to religion, was the puritanic severity in his own family.

and there is no passion produces so much mental agitation within the limits of pleasure as admiration; they afterwards expect a renovation of that pleasure, which was only the effect of surprise; and often the very recollection of that pleasure will keep alive the passion.

CHAP. XIII.

THE PASSIONS.

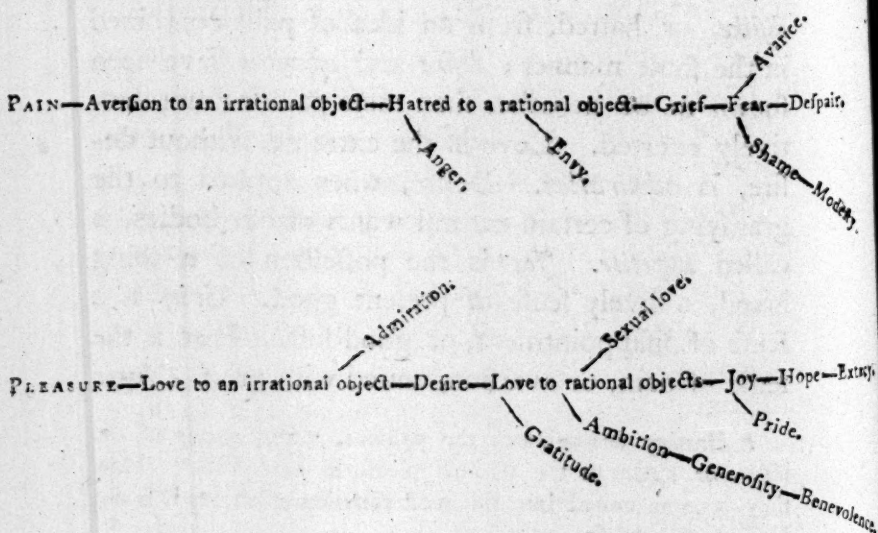
Of the Passions in general.—Particular Passions.—Associated Passions.—Paternal Love.—Sympathy.—Avarice.—Ambition.—Love.

IT may prove of the highest importance in morals to analyze the several affections and passions. The general cause has been already traced to the simple sense of pleasure and pain; we have seen further what it is that is called a sense of beauty *; and now, from the several modifications and combinations of these, we shall, perhaps, be able to form at least a conjecture how other more complex passions come to be formed.

Love having been proved to proceed from an idea of pleasure combined with another idea, and *dislike*, or hatred, from an idea of pain combined in the same manner; *desire* and *aversion* have been shewn to be no other than these passions more actively exerted. Love in the extreme, without desire, is *admiration*. Desire, when applied to the gratifying of certain natural wants of our bodies, is called *appetite*. Joy is the possession of a thing loved, a lively sense of present good. Grief is a sense of disappointment, or good lost. Fear is the sense of pain, or aversion, united with grief. Anger

* Hartley denominates the passions, "aggregates of the ideas, or traces of the sensible pleasures and pains." How they become united into the most common affections it is our business to explain.

is an extreme of aversion, united with a desire of removing the object. *Revenge* is a continuance of anger. *Envy* is anger excited through the desire of possessing what another man is possessed of. *Hatred* is the continuance of envy or resentment. *Hope* is a mixture of desire and joy. *Pride* is self-satisfaction, and is to ambition what joy is to desire. *Contempt* is a low degree of hatred or aversion, without any mixture of anger or of envy. *Curiosity* is desire excited by the natural love of action, often stimulated by appetite, or quickened by the love of beauty. *Shame* is fear arising from the social affections; that is, a fear of having done something that may lessen us in the esteem of others; it is the opposite of *Vanity*. *Despair* is nothing but an excess of grief. Perhaps the annexed scheme may contribute to elucidate the progress of the passions.



There

There is scarcely any such thing as a simple passion; even those which I have here specified are generally compounded with each other. Whatever ideas are predominant will determine the bent of the passion, much depending on the peculiar tone of the organs at different times. Some passions more easily mix than others.

Passions naturally terminate, when their end is accomplished. This, however, does not happen in all cases. It was remarked, that an impression, as it is more vivid, remains proportionably longer on the organ of sense; all the component simple parts of it are more strongly impressed, and it is associated with a greater number of ideas. Impressions accompanied with pain or pleasure are more vivid in proportion to the degrees of pain or pleasure, and such we must remember are all passions. These impressions and ideas are of course more vivid than any others, of course associated with a greater number of ideas, all of which will serve to recall them, and thus a passion becomes the cause of its own continuance, and by this means influences our train of thinking.

From what has been stated it appears, that passions are transferable from one object to another. An idea being often repeated with an idea which we love, and which of course gives us pleasure, we come at last to love the idea which was at first indifferent. What is more common than to love the children of those whom we esteem, and that for no merit or beauty in the children themselves? In parental love, the passion is in part transferred from self to the offspring. The mother, during
her

her pregnancy, connects the idea of the infant in her womb with a number of agreeable ideas, with pleasure and with hope; hence maternal love is stronger at first than paternal. The idea of duty, and the example of others, tend to increase the passion; afterwards custom, and the little cares about them. It is observable, that the love of parents is weak at first; but love rushes in by little associations as from a thousand sources.

On this principle depend some of the strongest affections that sway the human race. Every desire, for instance, is attended with a degree of uneasiness; to remove it, therefore, is pleasure. Now, when men once perceive certain agreeable consequences from obtaining an object, a desire of obtaining it ensues; this desire will be liable to be renewed, and will be renewed simply as a desire, without any retrospect to the first motives. This is evidently the case in avarice, where, dropping the immediate steps between money and happiness, men form a connection, which does by no means naturally and immediately exist, and love the treasure for its own sake. "The same might be observed concerning the thirst of knowledge, the delight of reading, planting, &c. These were first entered on with a view to some farther end, but at length become habitual amusements; the idea of pleasure is associated with them, when the first reason is quite vanished out of our minds; nay, we find this power of association so great, as not only to transport our passions and affections beyond their just bounds, both as to intenseness and duration, but also to transfer them to improper objects, and such

as are of a quite different nature from those to which our reason had at first directed them *."

I shall close this sketch of the passions by a short account of sympathy or social affection, and afterwards, by the history of those most powerful incentives to action, avarice, ambition, and the passion of love between the different sexes.

The pleasures of sympathy are generated, 1st, by that love to our fellow creatures, which is the effect of early obligation †. 2dly, Because the sight of any enjoyment excites in us the pleasurable ideas of that enjoyment, and unless envy interferes, these will ever have their due effect. These feelings are increased by the praise that is bestowed on benevolence, &c. and the hope of reward in another life. Sympathy in the misfortunes of others has a double effect; when beheld at a distance, as in theatrical representations, I believe most men find something rather pleasing than otherwise in them, and this arises from the pleasure that attends moderate emotion, even though derived from a painful source. In persons of very delicate sensations, this affection often degenerates into actual pain; and on beholding real woe, it is such to all who retain the common characteristics of humanity. Compassion, or the desire of relieving distress, is no

* Preliminary Dissertation to Law's Translation of King's Origin of Evil.

† The social pleasures and affections may, as Dr. Hartley observes, be much indebted for their increase to the pleasures of the palate. Since it has been customary in all ages to satisfy our appetites in the company of our nearest connections, the idea of pleasure will become combined with them.

other than a wish of removing pain. The sight of a wound excites immediately ideas of pain in our minds, and we feel a sensation of the same nature (though weaker) according to our memory of similar pains, or, as we by description judge of them, from the pains that we really have felt. To relieve distress, therefore, is actually taking off pain from ourselves; to the act of relieving we give the name *generosity*. The idea of the pleasure is afterwards excited by hearing of an act of generosity, nay, is associated with the very word itself, the mention of which, I believe, in most people, excites a grateful sensation. By these means, the virtue of sympathy may be constantly maintained, and every amiable passion cherished.

It has been already intimated whence the passion of avarice derives its origin. The natural wants of man, it is true, are very few; yet in the present state of society, these wants are not to be supplied without some exertions on our own parts. The first design, then, of human beings, is, to acquire such a competence as will satisfy the calls of nature. But observe what habit does. By a continued pursuit, we grow eager in the chase; the first object is lost sight of; we annex the idea of pleasure to the means or the instruments, and fancy riches have something in themselves desirable. A passion different from the first is now generated; one man's example imparts fresh vigour to another, and the end of life is forgotten in the ardour of an imaginary pursuit*. When the idea of pleasure is once

* "Et propter vitam, vivendi perdere causas."—Juv.

transferred

transferred thus to the instrument, we see a child prefer a piece of money to many actual gratifications that might be enjoyed immediately. I knew a covetous man, who hired a very uncomfortable large house, a third part of which he did not inhabit, because he thought it a good bargain to procure an house of that size at the same rate as a smaller. The same man left a pleasant farm and a good estate, and bought a commission in the army, purely because he could procure it at a *cheap* rate.

“Avarice is checked, 1st, By the strong desires of young persons, and others, after particular gratifications. 2dly, By considering the insignificance of riches in warding off death and diseases, also shame and contempt in many cases; and in obtaining the pleasures of friendship, religion, &c. 3dly, By the eager pursuit of any particular end, as learning, fame, &c. *.” We may observe, that avarice is only the passion of little minds, and will be chiefly predominant in uncultivated persons, whose attention cannot be drawn from it by nobler pursuits; and in old people, whose sensual passions are decayed.

Ambition seems to be founded, 1st, On the hatred or aversion to poverty, and all its concomitant disadvantages and inconveniencies. 2dly, On the experience that we are indebted to our fellow-creatures for many conveniencies of life; and from the habit generated even in children, of endeavouring to please them, in order to obtain many objects

* Hartley, prop. 48.

of pleasure to our senses. 3dly, Many of the constituents of natural and artificial beauty are possessed by those in high stations, we therefore annex pleasurable ideas to those stations, and love them on that account. 4thly, Custom, and the words usual in commendation, being applied to such persons, increase the passion.

Ambition will take a different course, according to the disposition or cast of thinking in different persons. Thus if a man is habitually sensual, his ambition will still have an inclination towards what may gratify his appetites. One man, perhaps, from education or example, has acquired a habit of admiring fine cloaths; another, from natural timidity, avoids shame and poverty. Commonwealths promote ambition of a different kind from that which is prevalent in monarchy. Ambition takes a different course, according to the time of life. It is to be remarked, that the primary constituents of this passion (as indeed in all others) will be obscured sometimes by the associated affections. The praise bestowed on the heads of certain sects of philosophers led many men to despise the natural objects of ambition, riches and pomp; and the natural dislike to poverty and dirt was subdued and forgotten.

The passion of love (and especially between refined persons) is of a very complex nature, and far removed from the sensual appetite, with which it is sometimes even very slightly connected. It is a well known fact, that an accomplished woman of fortune and family run off some years since with an Italian eunuch, whom she married for love.

The

The truth is, that besides the appetite, the social passion, as before explained, and this, heightened by the protection a weaker person seems to claim from us; the sense of beauty; admiration of particular accomplishments; the respect due to high birth or fortune; the commendation of others, and habit, in many respects concur more or less to form the passion.

Men of the world are all of them sensible what success may be derived from a pleasurable state of mind, in which the object, whom they wish to please, may happen to be. On this account they studiously mingle in all the pleasures and amusements, of whatever kind, in which that person is found to delight. It is a maxim of Lord Chesterfield, "Make a person in love with themselves, and they are certain to love you in return *." The pleasure of receiving gifts is directly connected with the object that bestows them; where presents cannot be made, praise and commendation are the ordinary means, and if their sincerity is not doubted, seldom fail of success. I question not, but it might almost secure the suit of a lover to be the messenger of some very agreeable piece of intelligence to his mistress. Pleasurable ideas, we know, are naturally connected with personal beauty, riches, high birth, great qualities, or fame. Some impostors, under the mask of being persons of rank, have insinuated themselves into the good graces of females; nor could the disagreeable ideas naturally annexed to

* One of our comic writers prescribes, that a man must first make a woman a friend before he ventures to appear as a lover.

falsehood and deception, afterwards vanquish the attachment. In fine, if by any means a man can become the associate of agreeable ideas, on the principles every where proved, I think, throughout this book, he may soon hope to obtain a part in the affections of his mistress; and this may serve to account, in some measure, for the many whimsical connections we are every day witnesses of.

- “ When Miss delights in her spinnet,
- “ A fidler may a fortune get;
- “ A blockhead with melodious voice,
- “ In boarding schools may have his choice;
- “ And oft the dancing master’s art
- “ Climbs from the toe to touch the heart;
- “ In learning let a nymph delight,
- “ The pedant gets a mistress by’t *.”

There is no greater mistake, than that the world is governed by motives of interest. Cool self-interest acts in very few instances. Where mankind are not swayed by the natural affections, that is, by those ideas with which pleasure is naturally connected, they are generally determined by some prejudice, that is, an idea with which pleasure or pain is fantastically combined.

There is, perhaps, no passion so improvable by association as love; it is connected with many ideas that tend to refine, soften, and elevate the soul, and to increase the passion under the appearance of increasing present pleasure. We are not to wonder, therefore, that it has proved so copious a means of

* Cadenus and Vanessa.

playing

playing with our feelings in poetical and dramatic compositions. To feel and sympathize with ambition we must be particularly circumstanced, and then our thoughts are generally too strongly bent on the pursuit to attend to imagination. Ambition is an active, love a sedentary passion.

Some conclusions in favour of the practicability of virtue will ensue from the preceding principles. In the first place, much of the government of the passions will hence appear to be in our own power, by avoiding pernicious associations, and by early care; hence we may learn how to restrain the enthusiasm of avarice and ambition, by tracing them to their source. In our choice of friends and books also, we may learn to be cautious to avoid those from which ill habits or prejudices may be derived; we may learn further to be aware of the effects of custom in acquiring a fondness for trifles, and especially for gaming, and other unnatural propensities; we may learn to direct our affections to proper objects, to associate the pleasing with the useful, or, by force of reason and resolution, to disentangle those improper combinations which we may have formed. This, indeed, seems to be the great use of reason and science, viz. to enable us to pursue the chain of associations, which our affections may have extended, and to discern plainly the *littleness* of the common and ruling passions of mankind.

C H A P. XIV.

O F R E A S O N I N G *.

Common Sense ; what.—Defective Reasoning.—Analogical Reasoning.—Wrong Data.—Pleasures of Reasoning.

REASONING may be defined a chain of judgments, following and depending upon one another, by which some general conclusion is attempted †.

The design of this chapter will principally be to exhibit some detached observations, such as may supply us with a few cautions against the most common defects in reasoning, which will be found in general to depend upon a false or unnatural association of ideas. Thus, repeated observation of the proper and usual relations of things produces a presumption in the mind, that those which are accidental may be equally well founded ; and this appears to be the undoubted cause of what is called prejudice.

* With this chapter the third division, or the miscellaneous part of this book, commences.

† “ Sense and memory are but knowledge of fact, which is a thing past and irrevocable ; science is the knowledge of consequences, and the dependence of one fact upon another, by which, out of what we can presently do, we know how to do something else when we will, or the like another time.”—Hobbes *Leviath.* pt. I. c. 5.

When

When the train of ideas flows in its natural course, that is, according to the true relations of things, then the opinions and conclusions formed will be just. When it is warped out of its natural course by an accidental association, then such opinion, and every action founded upon it, will be false. Thus, while men annex the idea of honour to patriotism, and that disinterested benevolence which prompts a generous spirit to disregard its own interest in contending for the safety and welfare of others, they reason according to the common order of nature; but if they by any means narrow the sentiment, and can persuade themselves that it is lawful to destroy or injure some for the sake of others, that false notion of honour is generated, which produces war, devastation, and conquest; if to this they annex the idea of insult, as heightening the honour, and add the idea of cruelty to insult, which the warmth of passion may readily lead them to do, or if it should seem a mark of courage to taste the blood of their enemies, they will think it honourable and right to torture, and perhaps to devour them *. That the universe must have a first cause, that a first cause

* "The beginnings of this corruption may be noted in many occurrences, as when an ambitious man, by the fame of his high attempts, a conqueror or a pirate by his boasted enterprises, raises in another person an esteem and admiration of that immoral and inhuman character, which deserves abhorrence; 'tis then that the hearer becomes corrupt, when he secretly approves the ill he hears; but on the other side, the man who loves and esteems another, as believing him to have that virtue which he has not, but only counterfeits, is not on this account either vicious or corrupt."—Shaftsbury's Enquiry con. Virtue, b. 1. p. 2. f. 3.

must be self-existent, that a self-existent being must be eternal, that an eternal and self-existent being must be without imperfection, is a chain of reasoning that leads directly to a knowledge of the wisdom and goodness of our Creator, and ought to inspire us with a desire of imitating his perfections ; but if, from personifying the deity*, men shall once give room to conceive of him as having parts and passions, fancy will soon be sportive on the occasion, and the amours of Jove, and the contentions of the Gods, will become a part of the popular religion. What effect such an error must have on morals is obvious. While surrounded with the bounties and mercies of God, we can never altogether lose the idea of his goodness ; if, therefore, to the admiration of the deity, the idea of vice or passion should be annexed, these will lose their deformity, and, however contrary to men's better judgments, such vices may even be held in esteem.

Some respectable writers have endeavoured to make a distinction between reason and what they call common-sense. But, perhaps, all that can be fairly asserted is, that some propositions are more nearly connected with sensible impressions than others, and

* Because we can have no distinct ideas, but those combinations which we form of sensible impressions, mankind have in all ages been inclined to personify the invisible first cause of the universe, for the sake of having a distinct idea of him ; and as the human form is the most familiar to them, as well as the most honourable, they have generally adopted that. This deception of our nature persevered in, has led them to assign him appetites, passions, &c. the same with the evil principle, and hence the origin of all superstition.—See *Essays Historical and Moral*.

therefore

therefore the train of reasoning is less liable to be diverted into a wrong conclusion, than in abstruse speculations, or those which are far removed from being objects of the senses, where the variety of associations affords a greater scope for error. Thus, "that things equal to one and the same thing are equal to one another;" "that nothing material exists without a cause;" "that, therefore, this world has a first cause," and such like, are propositions immediately connected with experience, and therefore admitted without hesitation. That the angles of a triangle are equal to two right angles, is a truth no less certain, but cannot be demonstrated without a considerable train of reasoning. This remark will apply to many disputes in morals, theology, &c. Those facts which lie nearest the testimony of our senses will meet the easiest reception.

I have called reasoning the arithmetic of words, in which false conclusions may be drawn, either from wrong data, or from an error in the operation. It will follow, that the conclusions of our reason, and our immediate feelings, may be sometimes at variance. It is common to say, "I feel confuted, but not convinced;" that is, on some former occasions, by common experience, you have united certain consequences with certain things or actions; and another person, by a certain chain of reasoning, some one step of which may be false, but to which you have not attended closely enough to detect the error, now exhibits a different conclusion. Passion itself will often play the part of the sophist, and determine men to act in contradiction to a conclu-

sion founded on common experience*: "Video meliora, proboque, deteriora sequor."

Errors most frequently happen in what is called reasoning by analogy. Analogical reasoning is grounded on the resembling parts of complex ideas, and as long as we are careful to note the proportions of those resembling parts, and how far in each of the compared ideas they may be connected with, and influenced by others, it will generally prove a safe method of reasoning; but as the associations are not near so strong in this relation, as in that of cause and effect, as the relation is more complex and more removed from common experience, this mode of reasoning will more frequently deceive us. Thus, "if we argue from the use and action of the stomach in one animal to those in another, supposed to be unknown, there will be a probable hazard of being mistaken, proportional in general to the known difference of the two animals, as well as a probable evidence for the truth of part, at least, of what is advanced, proportional to the general resemblance of the two animals; but if, on examination, the stomach, way of feeding, &c. of the second animal should be found, to sense, the same as in the first, the analogy might be considered

• As bodily pain is an unusual state, and can never be entirely forgotten, however engaged the person may be, but will of course awaken the attention frequently to such objects and ideas as are connected with it; so a passion, being an unusual state of mind, something analogous to the suffering of the body, will frequently awake it from other pursuits, and turn it to those ideas which are connected with it.

as an induction, properly so called, at least as approaching to it *."

Reasoning may likewise be defective and false, from accepting an axiom or conclusion drawn from a former judgment as an intuitive principle, or from an imperfect or partial view of the subject, and from what has been said of custom, it is evident that it may have a great influence over our reasoning. Since ideas by repetition become more vivid, and acquire more force if associated with pleasurable sensations, it follows that it will require much force to overcome this slavery, which the mind fabricates for itself, and that no less than demonstration from an actual appeal to the senses, or from acknowledged principles, will be able to undo it †.

The

* "It is often in our power to obtain an analogy where we cannot have an induction, in which case reasoning from analogy ought to be admitted; however, with all that uncertainty which properly belongs to it."—Hartley on Man. Prop. 39.

"The analogous natures of all the things about us are a great assistance in decyphering their properties, powers, laws, &c. inasmuch as what is minute or obscure in one may be explained and illustrated by the analogous particular in another, where it is large and clear; and thus all things become comments on each other in an endless reciprocation."—Hartley Prop. 39.

† The following may be taken as a general abstract of the most common fallacies which occur in reasoning.

1st. Taking an accidental conjunction of things for a necessary connection; as when from an *accident* we infer a property; when from an example we infer a rule; when from a single act we infer a habit. 2d. Taking that absolutely, which ought to be taken comparatively, or with certain limitations. The construction of language often leads into

The pleasures of successful reasoning result, 1st, From the action it gives to the mind; 2dly, From the pleasure connected with the end we propose to ourselves from the investigation. In fact there is a pleasure attendant on the accomplishment of every end or design; for as all the first actions of men have a tendency to the gratification of their appetites, and the fulfilling of this design has ever been attended with agreeable sensations, we expect the same on the accomplishment of every intention or action whatever.

into this fallacy; for in all languages it is common to use absolute or general terms, to signify things which carry in them some secret comparison; or to use unlimited terms to signify what, from its nature, must be limited. 3d. Taking for the cause an *occasion* or *concomitant*. 4th. Begging the question; *i. e.* assuming the thing to be proved from the premises. 5th. Mistaking the question. When the conclusion of the syllogism is not the thing that ought to be proved, but something else that is mistaken for it. 6th. When the consequence is mistaken; as if, because all Africans are black, it was taken for granted that all blacks were Africans. 7th. Propositions that are complex, and imply two affirmations, whereof one may be true and the other false; as when it is affirmed, *that such a man has left off playing the fool*—if granted, it implies that he has played the fool; if denied, seems to imply, that he does so still.

C H A P. XV.

O F T H E F I N E A R T S.

Musick. — Painting. — Poetry. — Wit.

THE chief sources of pleasure in works of art are, 1st, As far as they contain of the primary constituents of beauty. 2d, Resemblance to things which have pleased in our former life. 3d, Utility. 4th, A sense of the ingenuity required. 5th, Fashion, and a deference to the opinion of others.

Musick is agreeable, I might almost say entirely, from the combinations of notes naturally agreeable, or from the proper contrast of these notes; from the variety of emotions produced by these combinations, and from these emotions being judiciously contrasted; and I suppose good composers, whether acquainted or not with this general theory, have recourse to these principles*. Very little of the pleasure of musick has any relation to the gratification of appetite, or is at all associated pleasure. Indeed, the remembrance of certain sounds, which may have been combined with other ideas of actions

* It is worth consideration, whether the agreeable sounds are not the most frequent, and the dissonant the most uncommon, &c. Those sounds and combinations of sounds which resemble the human voice may, perhaps, by association, give rise to the agreeable of musick.

or passions, may, by recollection, be productive of associated pleasure, as well as of various emotions *.

Painting derives its chief power of pleasing from the happy imitation of objects that have the power of renewing agreeable sensations; yet here much depends on a judicious use and disposition of the primary elements of beauty: lively colours, proper contrasts, the waving line, are always attended to by excellent painters.

Poetry depends little on the primary ingredients of beauty or pleasure, except in what respects the measure of the verse; and one reason for the pleasure of verse I apprehend to be, the agitation occasioned by renewing ideas and sensations, such being the return of sounds, and this especially when properly enlivened with new ones. Perhaps in descriptive poetry the beauties of contrast may be proper to be attended to; thus it steals some of the beauties of both music and painting; but its chief power over the mind is derived from the associated or factitious sense of pleasure, and from a representation of those objects which, by interesting the passions, produce mental emotion. It is remarked, that imperfect characters are most agreeable in poetry; the reasons I suspect to be these: 1st, Because we find in them a picture of ourselves, and often a sort of excuse for our own frailties. 2dly, Because there is more of the sublime in occasional fallies of vice or passion, than in uniform goodness. 3dly, Because of the contrast between the good and bad parts of the character, the latter

* See Dryden's Ode to St. Cecilia.

really setting off and making more conspicuous the former. I have already mentioned the pleasure of figurative language, resulting from the variety of thought and emotion introduced by the two trains of ideas *; and it is remarkable that, "when figurative words have recurred so often as to excite the secondary idea instantaneously, they lose their peculiar beauty and force †." It is a mistake, when critics tell us that florid language is not the language of passion; experience amply convinces us of the contrary. The truth is, that sorrow, resentment, or any violent passion (provided the reason is not injured) renders the mind more active, and though it never wanders very far from the subject, yet it indulges itself in many excursions, still recurring to its origin.

The same qualities, but differing in the degree, are required to form both the poet and the orator; in the latter more solidity is wanted. An oration, if composed like a poem, would be too florid and desultory. Quintilian points out the first qualification of an orator to be a good man: this, above every other circumstance, predisposes the hearers in his favour; besides, it supposes him more inti-

* "Though the metaphor began in poverty (of language) it did not end there. When the analogy was just (and this often happened) there was something peculiarly pleasing in what was both new and yet familiar, so that the metaphor was then cultivated, not out of necessity, but for ornament, 'Tis thus that cloaths were first assumed to defend us against the cold, but came afterwards to be worn for distinction and decoration."

—Harris's Philological Enquiries.

† Hartley, prop. 46.

mately acquainted with the nature of virtue, and abler to speak in its favour with force and energy.

Wit is the calling together two or more differing ideas by some nice and unexpected connection, relation, or correspondence. The pleasure of wit consists, 1st, In surprise. 2dly, In the agitation produced by variety, and the different trains of thought. 3dly, In several agreeable ideas, which must be of course recalled *.

* "The same kind of contrasts and coincidences, which in low and comic things would be wit and humour, become the brilliant passages that affect and strike us most in grave poetry."
—Hartley.

"Omnia nostra, dum nascuntur, placent."—Quint. l. x. c. 3. The action of the mind in forming any work is pleasing; and even if it is such as carried with it a good deal of labour and consequently some pain, we feel joy on perfecting it.

CHAP. XVI.

OF MORALS.

Use of the Doctrine of Association in Morals.—Two Theories of Morals.—A Moral Sense.—The Arguments against a Moral Sense.—A strong Argument for Divine Revelation.

THE principal use of the doctrine of association, when applied to morals, will be, to induce us to reflect how little of our happiness depends immediately on sensual enjoyments, and how we may enlarge and improve our lot of pleasure, by cultivating those intellectual delights, which neither injure our health nor reputation, and yet are replete with the most exquisite delight.

Another point which this doctrine tends to establish, may, I think, be made of advantage to mankind, viz. that what is naturally good or ill in a temper depends on a few principles, which may be in a great measure counteracted by other ideas and associations sufficiently grounded and enforced. Hence it follows, that we may be in a considerable degree the framers of our own dispositions*; and inasmuch as reason must be our guide in morals, civilization is eminently of use to society, the great

* Disposition is a general term, implying the bent or general direction of the mind. Thus we say, an angry disposition, &c. or, *testiness* is a disposition to be angry.

advantage of which seems to consist in the increase of intellectual pleasure *.

Among moral writers, two theories, materially different, have long existed respecting the nature of our sentiments of virtue and vice. Our love of the former, and detestation of the latter, is by the one party asserted to be an instinctive principle, independent of knowledge, or of former ideas admitted by the five senses; and by the other, to be nothing more than the result of experience or information.

For the first of these hypotheses, the arguments are many and forcible. 1st. There are, it is observed, in all languages, words equivalent to duty and interest, which men have constantly distinguished in their signification. 2d. The emotions which are produced by the contemplation of what is right and wrong in conduct, are different from those which are produced by a calm regard to our own happiness; so much so, that we judge extremely differently of the conduct of other men, and of our-

* "It is of the utmost consequence to morality and religion, that the affections and passions should be analyzed into their simple compounding parts, by tracing the steps of the associations which concur to form them; for thus we may learn how to cherish and improve good ones, check and root out such as are mischievous and immoral, and how to suit our manner of life, in some tolerable measure, to our intellectual and religious wants," &c. "The world is, indeed, sufficiently stocked with general precepts for this purpose; and whoever will follow these faithfully, may expect good success. However, the doctrine of association, when traced up to the first rudiments of understanding and affection, unfolds such a scene as cannot fail both to instruct and alarm all such as have any degree of interested concern for themselves, or of a benevolent one for others."—Hartley.

selfes

selves in the same circumstances. 3d. The sentiment of approbation or disgust which is excited by any action is instantaneous, and not the effect of reasoning or deduction; these sentiments are also excited even in children, long before they have learned to make use of their reason, or to form in their own minds any regular judgment concerning the good or evil consequences of action. 4thly. The general agreement of all nations (only making some allowances for local circumstances) with respect to moral excellence or moral turpitude, is also cited as a proof that these sentiments must proceed from some general and instinctive principle. 5thly. It is asked, what is meant by the term conscience, and that uneasy sensation which accompanies guilt, if there is nothing constitutionally in man to direct him in the pursuit of good and the abhorrence of evil?

In opposition to this doctrine it is urged, with some plausibility, 1st, That the moral sense improves * with years and knowledge. What moral ideas, it is said, had the savage girl caught in the woods of Champagne? What had the young man of Chartres, who recovered his hearing at the age of twenty-four †? Uninformed persons of every nation

* This argument is, however, not decisive, since any one of our senses, and even our bodily powers, may be improved by practice and instruction.

† A young man of the town of Chartres, between the age of twenty-three and twenty-four, the son of a tradesman, and deaf and dumb from his birth, began to speak of a sudden, to the astonishment of the whole town. He gave them to understand, that, about three or four months before, he had heard the

nation have not an exquisite moral sense, and infants very little of it. 2dly, We feel, and resent as strongly, any thing which contradicts the religion or customs of our country as those vices which are generally disallowed, and this can by no means be suspected to be innate. 3dly. What is called virtue is generally profitable. Nor does it at all derogate from the honour of virtue, that it is founded on the immutable principles of truth: a much more honourable extraction than blind instinct. 4thly. The necessity which all religious

found of the bells, and was greatly surpris'd at this new and unknown sensation. After some time a kind of water issued from his left ear, and he then heard perfectly well with them both. During these three months he was sedulously employed in listening, without saying a word, and accustoming himself to speak softly, so as not to be heard, the words pronounced by others. He laboured hard also in perfecting himself in the pronunciation, and in the ideas attached to every sound. At length having supposed himself qualified to break silence, he declared that he could now speak, though as yet but imperfectly. Soon after, some able divines questioned him concerning his ideas of his past state; and principally with respect to God, his soul, the moral beauty of virtue, and deformity of vice. The young man, however, had not driven his solitary speculations into that channel. He had gone to mass, indeed, with his parents; had learned to sign himself with the cross, to kneel down, and to assume all the grimaces of a man in the act of devotion. But he did all this without any manner of knowledge of the intention or the cause; he saw others do the like, and that was enough for him. He knew nothing of death, nor did it even ever enter his mind. He led a life of pure animal instinct; and though entirely taken up with sensible objects, and such as were present, he did not seem to have made such reflections even on these as might have been expected; though he did not want understanding.—*Mem. Acad. Science 1703, p. 18, cited by Buffon.*

persons

persons admit of a divine revelation to teach us our duty, and the great imperfection of all the systems of morals that have proceeded from the Heathen sages *, seem greatly to militate against the hypothesis of an innate moral principle.

There are some points it is added, in which all men agree ; because there are some deductions, which all men endued with senses nearly alike, cannot fail to draw. There are some ideas which will be associated in every mind that reflects. Of this nature are the common opinions of virtue and vice. Every being sensible of pleasure and pain must also be sensible of love and hatred. Very little experience will convince any man that particular actions are attended with ill effects, and others in like manner with good ones. No matter whether to ourselves or others, we have the idea good and bad annexed to the actions, before we have the idea of the persons to whom they relate ; we have them from our own experience, or something adequate : we love the one and hate the other, we love whatever promotes the one, and the contrary.

We very early come to have a sense of injustice, since whatever disappoints the appetites, or is productive of present pain, generates resentment in an infant. These ideas are regulated by reasoning and education, and men in time learn to distinguish between a misfortune merited, or which they have brought upon themselves, and one which is brought upon them by others ; they learn too to distinguish

* See *Essays Historical and Moral. Essay, Principles of Morals.*

between chance and design, and hence our hatred to injustice, &c.

The quick sense of honour and shame, it is further alledged, can be no argument in favour of instinctive morality, for we are much more ashamed of natural defects; there are few men that would not rather be called knaves than fools.

The reason men are ashamed of sensual enjoyments, is the loathing and disgust that follow excess in them; there is no excess, no disgust, no satiety in the pleasures of imagination, we can therefore bear to reflect upon them.

Should we reject on these grounds the doctrine of an instinctive moral sense, the argument will, in my opinion, be extremely cogent in favour of the necessity of a divine revelation to confirm men in the right path of reason, and counteract those errors which false associations may produce.

CHAP. XVII.

OF GENIUS.

General Observations on what constitutes Genius.—Of the Varieties in Genius.—Genius opposed to Dulness.—Different Cast of Genius.

SOME men, it is well known, feel more acutely impressions on their senses than others, and these impressions probably remain longer vivid on some than on others. It seems not unlikely therefore, that this faculty of feeling more acutely, and the impressions on the senses dwelling longer vivid in some men than in others, enables them to form more extensive combinations, and connecting together more effectually their ideas, may constitute what is called genius, in opposition to stupidity or dullness*. Such a faculty will enable men to acquire knowledge more easily, by more readily admitting perceptions; to retain it better by the frequent repetitions, which so many associated ideas must produce; and to express it more readily from the connexion of ideas, which will recal each other in a more complete and regular series. Men of this

* Genius on these principles seems to be an active power of quickly combining simple ideas, or of discovering their combinations. Dulness to be no more than a sluggishness of mind, which is incapable of following the combinations of notes in a fine piece of music, or of the colours in a good landscape, though the simple ideas may be obvious enough.

description will have more objects of pleasure and of beauty than ordinary minds. Relations which would have escaped the majority of mankind, will be impressed on their senses, and combinations will be formed of which others could have no conception. Their minds branched out, in a manner, to more objects, will in fact have more sources of pain and pleasure; only that as the portion of pleasure is greater than that of pain in the world, their pleasures will be proportionably more numerous.

But there are other differences subsisting among men of apparently equal genius, which seem difficult to be accounted for. One man shall excel in an art for which another possesses no qualification, who yet is at the summit of excellence in some other. That the passions must have an effect in forming our disposition * and cast of thinking, cannot well be disputed; and the passions being no more than modifications of the appetites, on them must in some measure ultimately depend the turn of mind in particular persons.

I can easily conceive that one sense may be so perfectly and delicately organized, as to be more susceptible, to distinguish more nicely, and to present the ideas of that sense more perfect than the other senses; and this is probably the case with

* How far the natural frame of the body or the violence of appetite may influence the mind, is not easy to define. A delicate habit unable to bear the extremes of cold and heat, or any other inconvenience, may dispose the person to be cautious, suspicious, fretful. The same may in the end render him avaricious. On the other hand, there are passions which almost entirely depend on early associations of ideas.

those who possess a very fine musical ear without any acuteness of understanding. But in general this delicacy is extended to all the mental organs, or, to speak more properly, perhaps, to the mind itself. Hence a genius for all the fine arts commonly exists in the same person, and if they have applied only to one, we may reasonably conclude an early bent to have determined the preference.

It is allowed that a quick perception, a proper degree of retention, and a facility in recalling its ideas, are as essential to a sound judgment, as to a fine imagination *, the great difference seems to be, that the one selects and dwells upon such ideas as are necessary to its immediate purpose in discovering truth; the other selects only such as give pleasure, and does not dwell long upon any. It is probable therefore, that this is chiefly a difference in temper and disposition. Acuteness of feeling is

* The philosophic genius, according to Dr. Gerard, differs from a genius for the arts, in this, that the former is chiefly employed upon the relations of effects and causes, and the latter is attracted by the relation of resemblance, consequently the one dwells on a few principles, the other pursues every light and fanciful association.

“The philosopher describes minutely all the appearances of his object; his design requires it; every one of them involves some truth; inattention to any one of them may prevent the discovery of truth, or occasion error; those of them which seem least striking, often lead most directly to truth, or lead to the most important truths. A poet, on the contrary, would overlook by far the greatest part of these appearances; they are unfit to please, and for that reason attract no share of his attention: he fixes on a few that are most striking, and labours to set these in a striking light.”—Ger. on Gen. pt. 3. f. 1.

certainly ever connected with fine parts, being in fact no other than quick perception ; but it is certain, that among men of equally acute feelings, some are less violent and sanguine than others. I can by no means consent to refer this difference altogether to education, for persons who have had every possible care taken of their temper in early youth, will often, when set at liberty, break out, and become of very unruly dispositions in maturer age ; and persons will resemble their parents in temper, who have never seen them :

“ *Naturam expellas furcâ, tamen usque recurrit.*”

This fact we can refer to no one principle in human nature but the passions. Those whose animal appetites are stronger than those of others, will be more sanguine in all their desires, of course will smart more for a disappointment, and in a word, must be more subject to passion.

The old maxim, “ *Poeta nascitur,*” has been accounted a vulgar error, and it is certain much depends upon early habit, and this habit is always acquired from the circumstances of youth. But this does not entirely account for the difference of men’s pursuits, whose mental powers seem equal, and whose situations are similar. If once it is agreed, however, that a degree of coolness is necessary to certain studies, and that others are more connected with passion, we shall not long be at a loss to account for this seeming paradox in the human mind, upon the principles already established.

There are other causes of diversity in natural genius, such as difference in the degree, &c. One man

man is possessed of a more retentive memory than another; another man may have a more lively perception, and a little difference in principle will produce a great one in the effects. These persons may seem men of equal talents, and yet the bent of the genius will be different in each, and their qualifications different. After all, it is difficult to say what may be the effects of cultivation. Many excellent practical musicians are certainly not men of genius, nor ever possessed, as I have been informed, of a natural genius for their own art. What most commonly influences the pursuits and dispositions of men is, I am persuaded, custom*, early associations, and a predilection for certain occupations generated by some agreeable but fortuitous circumstance. Thus, in relating the life of the poet Cowley, Dr. Johnson informs us, that, "In the window of his mother's apartment, lay Spencer's Fairy

* Much of the difference between the scientific genius, and the genius for the arts will depend on early habit. "Persons (says Dr. Hartley) who give themselves much to mirth, wit, and humour, must thereby greatly disqualify their understandings for the search after truth; inasmuch as by the perpetual hunting after apparent and partial agreements and disagreements, as in words, and indirect, accidental circumstances; whilst the true natures of the things themselves afford real agreements and disagreements, that are very different or quite opposite, a man must by degrees pervert all his notions of things themselves, and become unable to see them as they really are, and as they appear to considerate, sober minded inquirers. He must lose all his associations of the visible ideas of things, their names, symbols, &c. with their usual practical relations and properties; and get in their stead accidental, indirect, and unnatural conjunctions of circumstances, that are really foreign to each other, or oppositions of those that are united."—Hartley p. 46.

Queen;

Queen; in which he very early took delight to read, till by feeling the charms of verse, he became, as he relates, irrecoverably a poet. Such (adds this great moralist) are the accidents, which sometimes remembered, and perhaps sometimes forgotten, produce that particular designation of mind, and propensity for some certain science, which is commonly called genius. True genius is a mind of large general powers, accidentally* determined to some particular direction. The great painter of the present age had the first fondness for his art excited by the perusal of Richardson's treatise *."

* Johnson's *Lives* vol. v. p. 2.

CHAP. XVIII,

OF TASTE.

Of Agreement and Disagreement in Taste.—Of a Standard of Taste.

DISAGREEMENT of taste, if we but attend to the principles explained in the former part of this book *, will be found to arise from particular associations †; and agreement in taste from the natural affections common to all mankind. The most perfect agreement will be between those whose genius, studies, and other circumstances most perfectly accord.

National taste is influenced by the same causes, which influence that of individuals ‡, and a slight association will frequently produce the most fantastical customs. The tyranny exercised over the female sex, the jealousy of the Asiatic nations; and the neglect of their women, shewn by some nor-

* See c. xi.

† From association, if glaring colours, or any other thing should be regarded by the country as a sign of levity or any other ill quality in the wearer; or if any colour or fashion is used by rustics, or men of a disagreeable profession or temper, these ideas recur with the fashion or colour.

‡ Almost every perception will introduce a different train of ideas in every different person, according to the different circumstances with which it may have been most frequently associated in each person's mind, and consequently often according to their particular occupation or profession.

thern barbarians, does not proceed from a coldness in the natural temper of the latter, nor from the more lively passions of the former; the truth is, in the rude state of those northern people, their other wants are so many, that they cannot attend to the pleasures of luxury. But the southern nations by the aid of a fine climate and a fertile soil, are more advanced in civilization than those of the north, though not arrived at that point when the mind is enabled, by reason and philosophy, to resist or correct false associations. The one party have little notion of pleasure, the others have mistaken notions of it. A single movement in the intellectual world influences a train of ideas, and if wrong, produces a series of misconduct. It is certainly a constituent of female beauty to have limbs smaller and more delicate than those of men; but mankind are ever desirous of pleasure and beauty to excess; the Chinese, therefore, endeavour to produce a degree of beauty beyond what nature has established as perfection, and cramp the feet of their women even to deformity: the same motive will serve to explain many fantastical fashions which occur to our own observation. What induced some of the Indians to colour the teeth black, was supposing it essential to men to differ from the brutes in every respect, and therefore it was necessary not even to have teeth of the same colour.

Deviations from nature happen chiefly in a state a few removes from barbarism. True refinement brings men round to the primitive simplicity from which they have been diverging. Whether the theory of a moral sense is admitted or not, it is still highly probable, that there is in all things a certain perfect-

perfection of which mankind is naturally emulous. The ideal characters, and the golden age of poets, exhibit the original traces of the consciousness of this perfection, written in the breast of every man. It is on this standard of excellence in human nature that a standard of taste probably depends. As men approach more or less this point of perfection, they are called polite or rustic, civilized or barbarous; and though the point itself has never, perhaps, been attained, nor ever will be attained by any, yet men there will be in every age who approach nearer to it than the great mass of mankind, and in some ages they will abound more than in others; from the number of these we are to form our judgment of the taste of any given period; these, in fact it is, who lead the fashion in thinking; and although there are degrees in this intellectual excellence, yet all men will be admirers and judges of perfection in arts or in morals, in an exact proportion as they approach perfection themselves, provided only they have made themselves perfectly acquainted with the principles of that art of which they presume to judge.

CHAP. XIX.

OF OPINION.

Paradox of the Stoics.—Explanation.—The sensible Pleasures more numerous than the sensible Pains.—The same with the intellectual Pleasures and Pains.

IT was a dogma of the stoics, that good and evil depend upon opinion—Take away the opinion (say they) and the evil is removed*. This paradox is, perhaps, not wholly incapable of explanation. Certain it is, that if we except the sensible pleasures and pains, much of our temporal happiness and misery does depend upon opinion; that is, upon an imaginary estimation or fear acquired from associations of ideas. What renders a particular walk or apartment agreeable after being for some time habituated to it? but that the idea of the place becomes entwined and connected with the pleasures enjoyed in it. What gives value to the lover's keep-sake or the miser's gold? not that either are of any use to them, but the one is associated with the pleasure of sympathy, the other with that of convenience †. The moralists, therefore,

* See M. Anton. Med. Arrian Passim.

† Darkness and obscurity are the only means by which the eye can be materially deceived in judging of bodies.—The fancies, therefore, of apparitions, whenever they arose, most probably took their rise from some misconception of this kind; and, indeed, the little probability there is that men could be deceived

fore, who assert that we may be, in a great measure, the fashioners of our own happiness, are, perhaps, not materially mistaken. The sensible pleasures are more numerous than the sensible pains; but the greater part of our happiness is intellectual, or formed by the imagination. If, therefore, we can become such masters in reasoning, as to analyze and decompose those passions which the imagination forms, the fairy fabrick is dissolved, and our uneasiness is removed. Nor need we be prevented from uniting together agreeable aggregates of ideas, in which work nature will assist, and for the reason above intimated, viz. because the sensible pleasures are more numerous than the sensible pains, and because the mind is only active in pursuit of pleasure.

deceived in the open day, made obscurity be always chosen as the proper scene for terrors of this kind. Nay, the fear and caution which people must have in the dark on account of the danger there is of falling or injuring themselves; the opportunity it affords for ambuscades, &c. and being the common time for committing murders, &c. must increase this apprehension. Besides it deprives us in some measure of society, and cuts off many pleasing trains of ideas which objects in the light introduce. After all, probably so much of our happiness depends on the action of our senses, that the deprivation of any one of them is attended with proportionable uneasiness. Much use has been made of this principle in the gloomy construction of religious buildings, &c. superstition being the common offspring of fear.

CHAP. XX.

OF THE FREE AGENCY OF MAN.

Predestination, or fatal Necessity, not connected with the Doctrine of the Association of Ideas.—Inconsistency of the Fatalists.—Motive and Action in Morals totally different from Cause and Effect in Physics.—The Onus Probandi in this Question lies on the Fatalists.—Question concerning the Influence of Motives.—Argument of the Fatalists from the Divine Prescience.—Absurd and horrible Consequences resulting from the Doctrine of Fatality.—Modesty and Humility recommended in philosophical Studies.—Those Sciences to be preferred which are most connected with practical Utility.

THAT the doctrine of the association of ideas should, in the mind of any visionary writer, have ever been connected with the fatal necessity of human actions, is, I confess, to me a matter of surprise. Miserable, indeed, must be the state of man, if he was endued with no power of regulating or directing the train of his ideas; if they must flow for ever in one necessary, unbroken channel, or if external objects alone were to dictate to us what to think. It is obvious, that if this was the case, there could be no variety, and scarcely any change in the pursuits of men: the thoughts must flow from each other in one uninterrupted series, and man could not be an accountable, and scarcely a rational creature.

It is, however, plain, that we have a power of interrupting the train of thought, of dwelling more intensely

intensely upon particular ideas, and even of occasionally diverting our reflections and contemplations into new channels; and this power alone is sufficient, in my opinion, to constitute man a free agent*. Indeed those authors, who contend most for the doctrine of a fatal necessity, are among the first to recommend an application to study, and the cultivation of the mind; whereas, if the mind is endued with no spontaneous energy whatever, no self-directing agency, surely such a recommendation is inconsistent and absurd†.

On any question of serious importance, analogical reasoning should be admitted with the utmost

* It is impossible to observe, without a smile, men boasting of being the disciples of Mr. Locke, who have apparently never read a page of his writings, or, if they have looked into them, have evidently misunderstood them. With how much justice this *real* philosopher is represented as a favourer of the absurdities of the fatalists, will appear from the following passage: "This at least (says Mr. Locke) I think evident, that we find in ourselves a power to begin or forbear, continue or end several actions of our minds, and motions of our bodies, barely by a thought or preference of the mind ordering, or, as it were, commanding the doing or not doing such or such a particular action. This power which the mind has thus to order the consideration of any idea, or the forbearing to consider it, or to prefer the motion of any part of the body to its rest, and *vice versa*, in any particular instance, is what we call the will."—Locke's Essay, B. ii. c. 21.

† If there is no degree of freedom or spontaneity in human actions, what is meant by the words deliberation, prudence, and judgment? If the opinion of the fatalists is true, our interference in any matter or action is superfluous; and yet who is there that does not perceive, that the course of a dangerous disease may be impeded by the calling in of a physician? a matter which was entirely within the choice of the patient himself.

caution; and yet a senseless and puerile analogy has been called in to the aid of an argument, which cannot be supported by positive proof. Motive and action in morals, have been compared to cause and effect in physics*. That some motive in the mind precedes every human action is certain, and thus far the analogy is just; but the motive may as well be in the will itself, as the mere result of any external cause. If, indeed, the analogy was true in all its parts, a human being would be altogether as subject to the laws of inert matter as a block of marble or of wood. Whatever is subject to an absolute necessity, can never be the incipient cause, or the beginner of motion or action of any kind; it must be altogether under the command and direction of external objects; it must be altogether inert or passive, having no principle of action in itself. On this account, as I before intimated, there would be much more uniformity in the actions

* The arguments by which the atheists have attempted to prove this analogy, are the most absurd and puerile that can well be imagined. "Every effect," say they, "must proceed from some cause, and this cause must be dependent on another." The direct conclusion from this is, "that there is no where any origin or beginning of motion, but every thing is necessarily produced by an eternal chain of causes and effects, without any independent origin." Such reasoning as this exactly resembles that of the Indian, who supposes the earth to rest on a crocodile, the crocodile on an elephant—but what does the elephant rest on? In fact, to compare the operations of the mind to any of the qualities of matter, is to compare, as Dr. Clarke observes, a square to the colour of blue, or a triangle to a sound. It is like the blind man, who, being asked what idea he had of *scarlet*, said, he fancied it must be something like the sound of a drum.

of

of men, if they were subject to a *fatal* influence, than there appears to be; there would be no difficulty in deciding what must be their conduct in any given circumstances.

A freedom of deliberating, chusing, and determining upon things, is what every man feels in himself *. It is the dictate of nature and common sense; one of the first perceptions we have of the operations of our own minds. It does not lie with us, therefore, to prove, that the human mind is free; but it lies with the opponents of liberty to *prove*, that *it is not free*; and this ought to be done upon direct, positive, experimental evidence, and not upon fanciful analogies or conjecture.

The only argument which the fatalists have ever been able to adduce, which at all bears upon the point, is this—that men act from motives, and these motives are dependent upon situation and external circumstances. This, then, is really the point at issue between the fatalists, and the advocates for the free agency of man. The former suppose the influence of motives from external causes to be absolute and unlimited; the latter allow the influence of motives to a certain extent, but they deny that it is absolute and unlimited.

In the present state of human knowledge, it is, indeed, a species of dogmatism not to be endured, to pretend precisely to ascertain how far the in-

* "As it is in the motions of the body, so it is in the thoughts of our minds; where any one is such, that we have power to take it up, or lay it by, according to the preference of the mind, there we are at liberty."—Locke's Essay, B. ii. c. 21.

fluence of external motives extends over the mind of man. That external causes should have a certain weight and influence with us, is certainly consistent with the wisdom of Divine Providence, and consistent with that order and regularity which he has every where established. If men were to act entirely independent of all influence from external causes and circumstances, the world would be an entire scene of confusion and disorder; if, on the contrary, they were endued with no power of choice or deliberation, the whole would be an inanimate uniform mass, subject to certain and definite laws, as much as inert matter. In this, therefore, the same happy medium appears to be established as in other instances. Man, from his natural relation to external things; from that wonderful connection which exists between the body and the mind, is subject to a certain influence from situation and circumstances; but there is still in his own mind a power of reflecting, deliberating, and deciding upon his motives and conduct.

Another argument in favour of fatality is deduced from the prescience of the Deity. "If God foreknows all things (it is alleged) then every event must be predetermined." But this argument rests upon the same presumptuous foundation as the preceding, which would positively determine the precise degree of *influence* that external causes must have upon the mind of man. Dogmatism certainly never was the road to truth, and is utterly inconsistent with that modesty and humility, which is the very characteristic of a real philosopher. The prescience of the Deity! Who will dare to say

say that he is able to define it? Who will dare to allege that he understands every particular circumstance and attribute of the Divine existence? To say that God *cannot* exercise his own powers in that way which is most agreeable to the ends that infinite wisdom proposes, and infinite goodness would dictate, is, to define and limit omnipotence! and to affirm that God cannot constitute man a free agent, *cannot* in this instance dispense with his own prescience, is to say, that God is not omnipotent. This was long my own opinion; and I was happy to find it confirmed by the excellent and judicious Dr. Henry More, whose sentiments on this subject were pointed out to me by a friend. "It is true (says he) we cannot otherwise think of God's *fore-knowledge*, but as being every way clear and perfect, and without possibility of error, as to those objects about which he judges or pronounces. And surely he does always judge and determine of things according as they are; that is to say, of a contingent thing, as it is contingent; and of a necessary-thing as it is necessary. Whence it comes to pass, that those things which are contingent and proceed from a free principle of acting, are allowed to be seen by God's consent.

"But, not to confine God's *omniscience* within narrower, nor ascribe to it wider bounds than we do to his *omnipotence*, which all suppose to be an ability to do whatever implies not a contradiction; let us dispatch the difficulty in a few words, by saying, that the *fore-knowledge of contingent effects*, which proceed from a *free principle of acting*, does either imply a contradiction, or it does not. If it does

imply a contradiction, then such effects are not the object of God's *omniscience*, nor determined by it, nor rightly supposed to be determined at all. But if it does not imply a contradiction, then we actually confess, that *divine prescience*, and *human free-will*, are not inconsistent, but that they may stand together."

The most decisive argument, however, against the fatalists, is, the extravagant conclusions to which this gloomy and comfortless doctrine leads, and the horrible consequences which are attached to it. If man is a *necessary* agent, he cannot possibly be an accountable being; for how preposterous is the thought, how inconsistent would it be with every principle of justice, to punish any being whatever, or in any degree, for what he could not have avoided? In a theological view, therefore, this doctrine appears to conduct directly to atheism; for we cannot conceive of the Deity in such a manner as to suppose him wantonly cruel or unjust. To say that future punishments are not to be (as the orthodox party conceive) eternal in their duration, does not remove the difficulty; to punish *at all* for involuntary offences, is cruelty and injustice. The system of free agency, on the contrary, is consistent with all the attributes of God, and is highly consolatory and instructive to man. This system rests upon the clearest basis of justice. Man is created free; he has good and evil placed before him, with the strongest and most conciliating motives in the Christian dispensation to pursue the one, and to avoid the other. If he perversely takes the wrong course, and proves incorrigibly

gibly wicked, every principle of reason and equity, sanctions the justice of his punishment.—Into the nature of that punishment, it is not my present business to inquire. It will doubtless be such as to satisfy infinite justice, yet tempered by the sweet and salutary exercise of infinite mercy.

If the divine laws are thus outraged by the preposterous hypothesis of a fatal necessity; human laws, I fear, will not stand upon a much firmer foundation. To punish any criminal for an error which he could not avoid, is certainly not only cruel, but wicked in the extreme; and yet such must be the case, if the doctrine of the fatalists is true*.

On the whole, it is the part of true philosophy to avoid equally the dangerous extremes of an arrogant dogmatism, which professes, like the ignorant opponents of Socrates, to know every thing,

* In the course of a very few years, it will scarcely be credited, that a book has been lately published on this very principle, and the argument of the author is briefly this. Man is a necessary agent, he is therefore not an accountable being; his actions are all determined by his situation and circumstances, taking in amongst these his education and the degree of knowledge he has been enabled to acquire. What are called *crimes* therefore are only *mistakes*, perfectly involuntary on his part, and he therefore (whether he is a thief, a murderer, or a parricide) *ought not to be punished*, but *instructed* and reasoned with. As no criminal ought to be punished, all laws or regulations must be perfectly nugatory in society, and even pernicious; marriage is law, and therefore it is pernicious, and ought to be abolished.—It is happy for the cause of truth, when such books are published; for if the sarcastic genius of a Swift could have more effectually burlesqued the doctrine of necessity, I am no judge of *irony*.

and of that perplexing skepticism which would deprive the human understanding of capacity and intelligence. As finite beings, many facts are necessarily placed beyond the reach of our researches. They are neither suited to our faculties, nor our situation in this life; and where we have no basis of fact on which to reason, error will generally be the consequence of our indulging in visionary speculations.

To console us for this deficiency, we may still remark, with satisfaction and gratitude, that if much is concealed, much also is known. There is an immense fund of practical knowledge perfectly within the grasp of our faculties. There is scarcely any human science, which, to know it well, is not sufficient to employ the most protracted existence of man. It will be more consistent with happiness, as well as with modesty, to acquaint ourselves with these, before we launch into the unfathomable abyss of metaphysical speculation; nor indeed can any thing be more disgusting, than to hear a loquacious disputant, who is unacquainted with the plainest and most useful branches of knowledge, presuming to arraign the appointments of omniscience, to "re-judge his justice;" to annihilate the intellectual, and to confuse and disturb the moral world. Much greater is his merit, much sounder is his judgment, who fabricates the simplest machine, or plans or executes the plainest undertaking that may be practically useful to mankind.

Yet we may innocently amuse our curiosity; we may innocently gratify our thirst of knowledge; we may innocently exercise our faculties. But let
us,

us, in the name of reason, exercise them on their proper objects; let us seek for knowledge where it is really to be found; let our curiosity employ itself where fact, experiment, and observation, may lead to some certain conclusion. The book of nature is open to us; the material world is displayed for our inspection, and for our improvement; the intellectual world is covered with an almost impenetrable veil. What God has chosen to reveal of himself in the holy scriptures, may be easily comprehended; what he has chosen for the present to keep in reserve, no mortal efforts will ever be able to develope. The simplest and most unlearned person who studies with a pure heart, and an undepraved mind, the sacred volume, is practically wise; the brightest understanding, the most exalted genius, who attempts to go beyond it, becomes inevitably a fool.

THE END.

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